

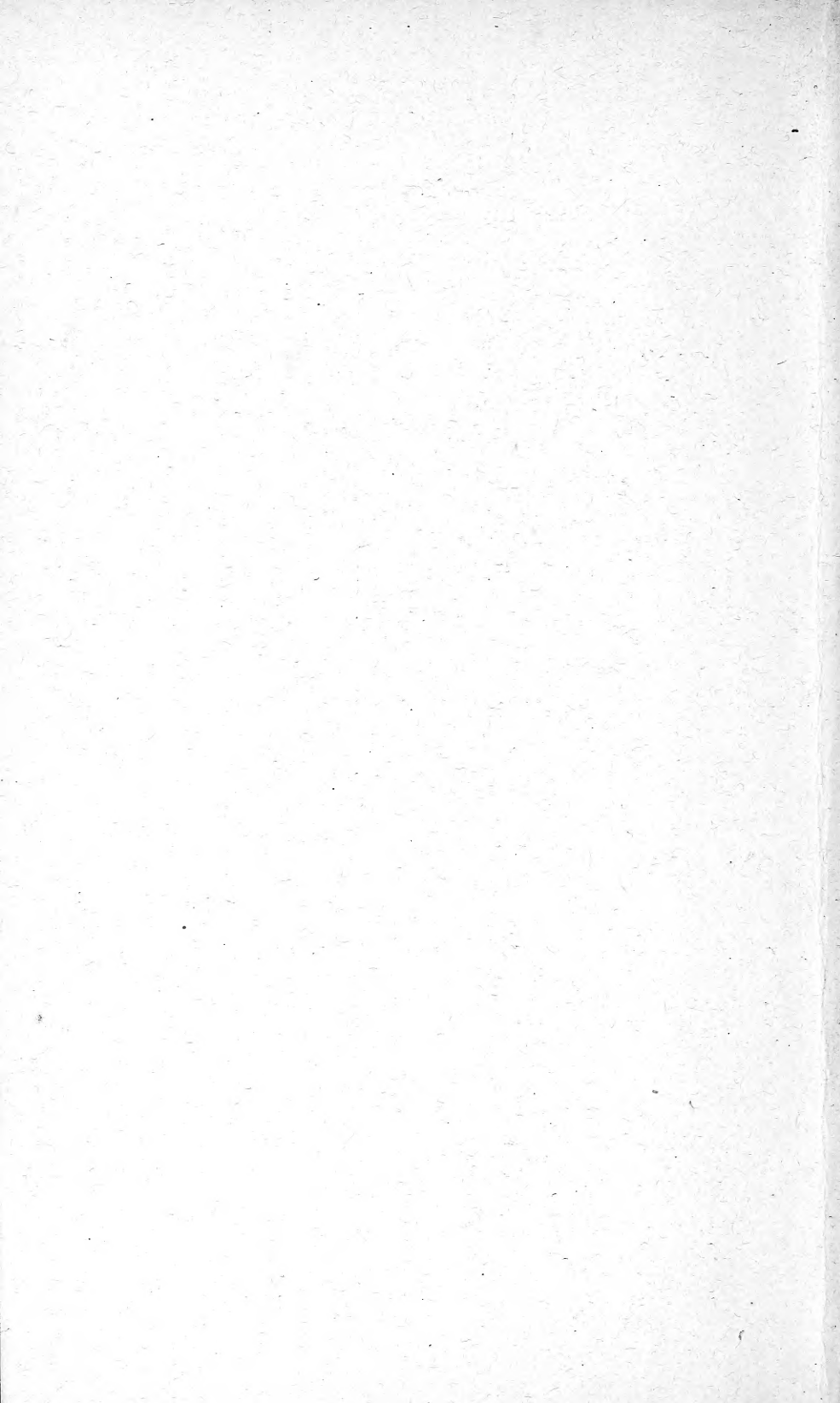
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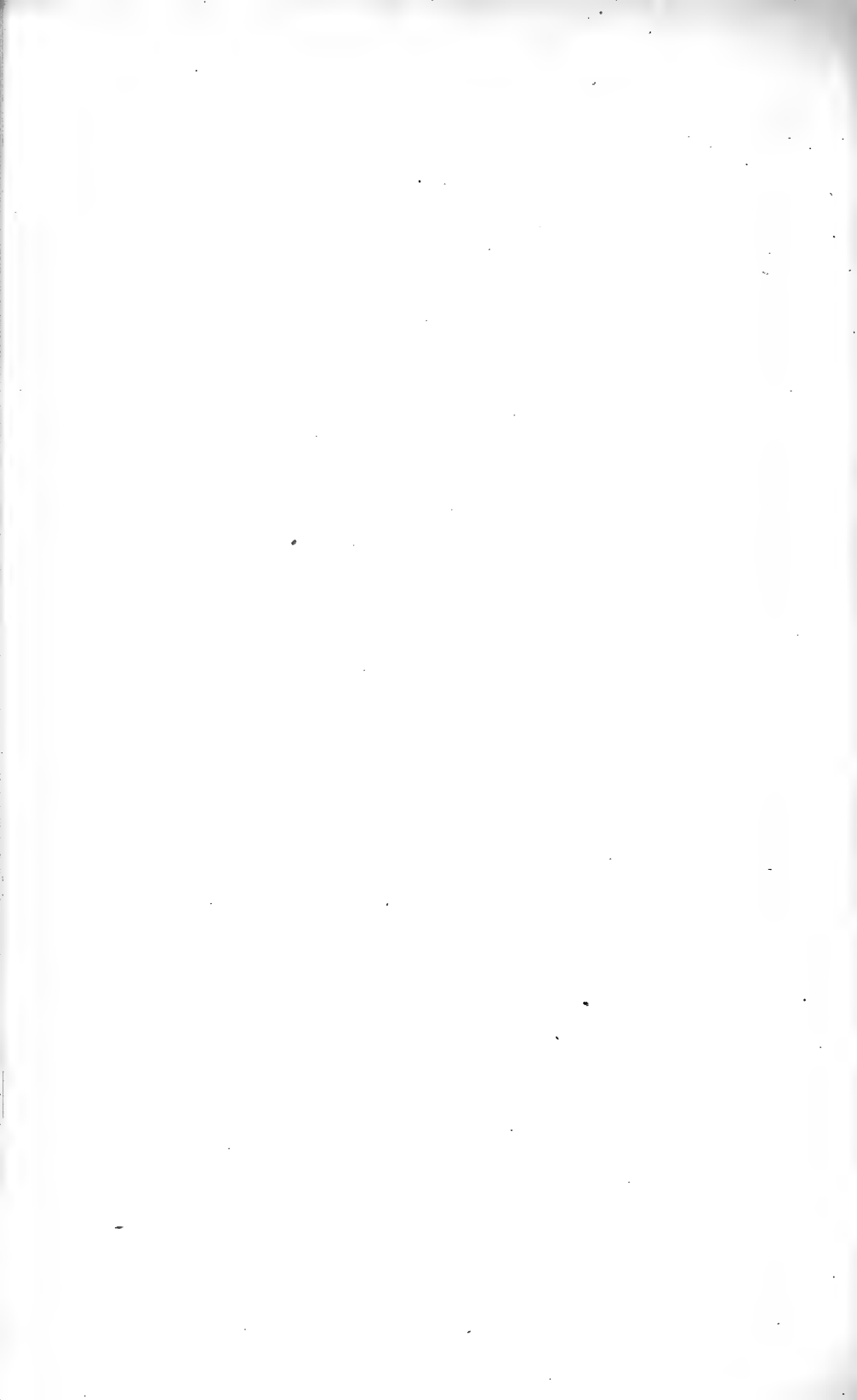
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UNITED STATES DEPARTMENT OF AGRICULTURE



BULLETIN No. 301

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HENRY W. HENSHAW, Chief



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SILVER FOX FARMING IN EASTERN
NORTH AMERICA.

By NED DEARBORN, *Assistant Biologist.*

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INTRODUCTION.

Furs are the most useful and valuable of the several products derived from wild animals. Indispensable to primitive man, they are scarcely less important to the civilized, for in warmth, beauty, and durability no manufactured fabrics equal them. As the result of increase of population and of encroachments upon the breeding grounds of the fur bearers the supply of furs has steadily diminished and prices have correspondingly advanced. Trappers have been stimulated to penetrate farther and farther into the uninhabited regions of the north and to redouble their efforts to increase their catch nearer home. Many of the more valuable animals are now so scarce that the demand for their pelts is met by the substitution of inferior products. Among the most important of the fur bearers of North America is the silver fox, which furnishes the subject of this bulletin.

The natural production of first-class furs seems to be approaching a sure end, and the growing and world-wide demand for them requires that the present supply be supplemented with stock obtained through domestication. Experience has demonstrated that some of the fur bearers may be raised without much difficulty. This is likely to lead

to the establishment of fur farming on a small scale as an additional source of income on farms in many places along our northern border, much as poultry is now raised. When properly conducted, fur farming may become very profitable. It will pay not only in direct returns to the producer but, indirectly, the natural and legitimate desire for furs can be gratified, the extirpation of the most valuable and interesting of our fur bearers can be prevented, and an extensive department of manufacture and trade supporting a large population can be continued.

Success in domesticating wild animals, as in other branches of husbandry, depends on experience, adaptability, and prudence. No one should engage in the business unless he enjoys it and is familiar with the habits, characteristics, and climatic requirements of the animals he intends to propagate. The choice of location is of prime importance. The best furs come from cool, moderately humid regions. If a locality furnishes native furs of high grade, that locality is favorable to the domestication of fur bearers. The climate of the Middle and Southern States is not well suited to this industry, as shown by the medium or low prices commanded by furs from these areas. The ratio of expense to income must be considered with care. One can not pay the exorbitant prices animals for stocking purposes sometimes bring and expect to raise fur at a profit. Neither can one expect to raise furs of a fine quality from inferior stock. But given a normal market for breeding-stock and pelts, a favorable location, a love for animals, and an ordinary degree of prudence, one may engage in black or silver fox farming with a good prospect of satisfactory returns, provided, of course, a high price for pelts is sustained. Values of animals and pelts were very high a few years ago, when the industry was being launched, but are now on a much lower basis. Persons who contemplate going actively into the business or investing their money in corporations or companies organized for fox farming should thoroughly investigate it in all its phases.

THE SILVER FOX.

The name "silver fox," as commonly used by furriers, includes the dark phases of the ordinary red fox,¹ variously called silver, silver gray, silver black, or black. It should not be confused with the gray, or tree, fox² of the United States, the fur of which is of comparatively little value. The color of the red fox of the Northeastern States and of its allies of the colder parts of North America varies from red to black, and these extremes, with their gradations, form four more or less distinct phases, known respectively as red, cross (or patch), silver, and black. In the red phase the fur is entirely

¹ Genus *Vulpes*.

² Genus *Urocyon*.

rich fulvous, except for restricted black markings on the feet and ears, a white area at the end of the tail, and certain white-tipped hairs on the back and rump. Grading into the next phase the black increases in extent until, in the typical cross fox, the black predominates on the feet, legs, and underparts, while fulvous overlaying black covers most of the head, shoulders, and back. A gradual increase of the black and elimination of the fulvous, or its replacement by white, results in the next phase, the silver (or silver gray) fox (fig. 1), in which the entire pelage is dark at the base and heavily or lightly overlaid with grayish white. The color of silver foxes varies from grizzly to pure black, except for a few white-tipped hairs on the back

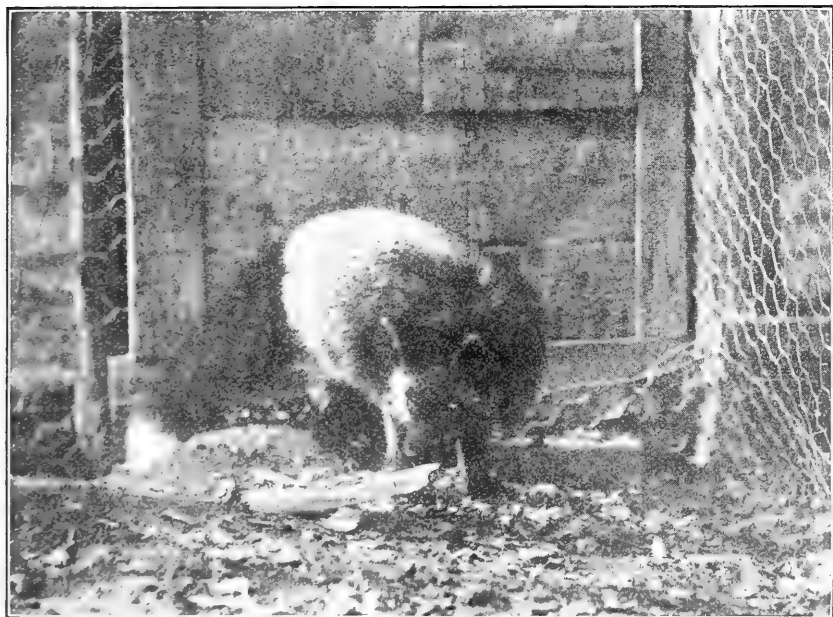


FIG. 1.—A silver fox.

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and rump. Finally, in the black phase, the white is absent from all parts except the tip of the tail, which is white in all four phases. The red phase is much more abundant than the others, but all four interbreed freely, and wherever one occurs occasional examples of the others may be expected. In general the cross fox is fairly common, the silver gray scarce, and the pure black very rare.

The market value of skins of the different phases depends upon the relative scarcity of the animals. The price paid for black skins, however, has recently fallen considerably below that of silvers, for the reason that furriers now dye ordinary red fox skins a lustrous black, and put them on the market at a comparatively low figure.

HISTORY OF DOMESTICATION.

Domestication of the fox was first achieved in 1894 by Robert T. Oulton and Charles Dalton on Prince Edward Island, a Canadian Province in the Gulf of St. Lawrence. Silver fox pelts have continuously commanded high prices, and hunters have been correspondingly keen to secure them. It is not strange, therefore, that the first successful breeders of this rare animal were men who had pursued it in the chase. The two mentioned had hunted foxes together and had frequently bought and sold fox pelts of their neighbors. Oulton was once lucky enough to shoot a silver fox the skin of which netted \$138. Becoming impressed with the possibility of domesticating such valuable fur bearers, Oulton and Dalton separately experimented in building fox-proof fences and in feeding and breeding the animals. After several years' work on these problems they formed a partnership in 1894, built a ranch, and stocked it with two pairs of silver foxes. This became the first profitable-fox ranch, the forerunner of a remarkable and, for that region, a revolutionizing industry.

At that time black pelts brought much higher prices than silver pelts. This prompted Oulton & Dalton to retain their darker animals and dispose of the lighter ones, and as a result each successive lot of pelts from their yards was darker than those of previous years. Finally, in 1910, they were able to send to the London sales the finest collection of silver fox pelts that had ever appeared there. This lot, containing 25 pelts, brought an average of \$1,386 each, the best one selling for \$2,624. In the meantime a few other small ranches had been started in the Maritime Provinces, Newfoundland, Maine, Ontario, Michigan, and Alaska. The policy of the half dozen Prince Edward Islanders in that business had been to monopolize it. They had kept their own counsel, and not even their families were enlightened as to methods. The pelts had been shipped three in a package by parcel post from a distant post office, and reports of the sales had been received in code. The fox raisers had entered into a compact to sell no live silver foxes and had bought the best that could be obtained. Notwithstanding their secrecy, the evident improvement in their financial conditions was noticed by their neighbors, who thereupon desired to participate.

Disclosure of the results of the 1910 sales was the climax of the first stage in the development of fox farming. People who formerly had known something of the business were now eager to engage in it. Those having money invested it in foxes. Others mortgaged their farms for the purpose or fitted up ranching facilities and boarded foxes for a share of the progeny. How rapidly prices for breeding stock advanced is well illustrated by the experience of one ranchman who sold his first pair of cubs for \$750, and other pairs successively for \$3,000, \$12,000, \$13,000, and \$14,000. In the fall of 1913 good ranch-bred cubs 6 months old sold for from \$11,000 to \$15,000 a

pair. Pairs that had had large litters were valued at about twice as much as 6-months-old cubs.

The maintenance of this prodigious inflation of prices was due mainly to stock companies, which originally were formed by individuals without sufficient capital to engage in fox farming alone. Almost immediately, however, companies were formed for the benefit of those having foxes to sell. It was customary for a company to take them over. An attractive prospectus containing pictures of silver foxes, an account of the 1910 sale of pelts, and a list of companies which had paid dividends of 20 to 500 per cent was published, and the stock sold through brokers and solicitors. Foxes that would bring \$12,000 or \$15,000 a pair in the open market were usually capitalized in companies at \$18,000 or \$20,000, which, after allowing for commissions, installation of pens, and other ranch necessities, left a tolerably safe balance from which to pay the first year's running expenses. Another reason for the multiplication of fox companies is found in the income to be derived from them by brokers and promoters, and many companies were formed by men having no other interest. The outbreak of the European war, in the summer of 1914, interrupted and probably ended these speculative operations. Ranch-bred silver foxes have recently been advertised for sale at from \$1,500 to \$2,000 a pair. In some of the western Provinces and Territories of Canada, where only those foxes born or kept for a year or more in captivity are allowed to be exported, prices of wild half-grown silvers run from \$150 to \$250 each. Prior to the war a general stagnation in the fur trade was beginning to have a depressing influence on prices of live foxes. The June, 1914, sale of silver fox skins in London averaged only about \$118 each. From present indications values of foxes and of pelts are likely soon to fall as low as they were before 1910.

In the pioneer days, when proper methods of handling foxes were unknown, many failures resulted from ignorance and carelessness. The excitement following the fur sales of 1910 hastened the improvement of methods of feeding, handling, and breeding. It also broke the monopoly, and caused a rapid distribution of foxes and of information concerning them. Now, with a comparatively large number of silver foxes in domestication, with a clearer understanding of their successful management, and with a return of moderate prices for breeders, a steady, healthy, and general development of silver fox farming may be expected.

Fox ranches are established in most of the Canadian Provinces and in Maine, New Hampshire, Massachusetts, New York, Pennsylvania, Ohio, Wisconsin, Michigan, Minnesota, Missouri, Oregon, Washington, and Alaska. In 1913 there were 277 fox ranches on Prince Edward Island alone. There foxes have the same status as other domestic animals in being subject to taxation; this in 1913 yielded the Province a revenue of \$37,172. In a recent report written from

Charlottetown by Consul Livingston T. Mays the number of domestic silver foxes on Prince Edward Island in April, 1914, was given as about 1,600, and in the following December as about 2,600, the increase for the year being approximately 66 per cent, or considerably below the average increase of former years. The value of the foxes on this island at the close of 1913, as estimated by the Commissioner of Agriculture, was over \$15,000,000. A report of the provincial secretary, issued May 7, 1914, shows that there had been incorporated in the Province up to that time 196 fur-farming companies, nearly all of which were devoted to fox raising, carrying an authorized capitalization of \$24,305,700. In December, 1914, the United States consul on Prince Edward Island reported that the capitalization had reached \$31,500,000. From the foregoing it is evident that anyone contemplating an investment in fox farming, either directly or in the stock of an organized company, should first carefully consider all values in their relation to the actual returns possible from the average increase of the breeding stock. As pointed out elsewhere in this bulletin, prices of both live silver foxes and fox pelts are now far below prices paid a few years ago. The business of fox breeding will be on a much more stable basis than at present when the value of breeding animals bears an approximate relation to the value of their pelts in the open market.

AREA SUITED FOR FOX FARMING.

The natural habitat of red, cross, and silver foxes includes the greater part of North America, from central United States northward to and including the border of the treeless tundras. The red phase inhabits nearly all this region, but the silver phase, although known from most parts of it, is very irregularly distributed. In general it is much more common in northern localities than in southern, but many parts of the north where red foxes are abundant produce silvers only rarely. According to reports of wholesale fur buyers, many silver fox skins of high quality are secured from Newfoundland, the height of land between Quebec and the peninsula of Labrador, and from the upper Yukon in Yukon Territory and the adjacent region of east-central Alaska.

While pelts of all fur-bearing animals are more valuable when produced in northern localities, furriers have learned that certain localities are not too far south to produce valuable furs, but the conclusions they are able to form are of only very general application. The ordinary individual, however, is seldom able to profit by the experience of furriers; and, especially if he lives in a region in which fur-bearing animals have been exterminated, he can not judge whether his own locality is favorably situated for producing foxes with valuable pelts. Fortunately, in a general way a guide to such matters is furnished by maps of life zones of the United States. These zones are transcontinental belts, throughout which the animal

and plant life have a certain uniformity. To determine the regions suitable for fox farming, therefore, it is necessary to learn the areas within which foxes are known to produce superior fur. Records of

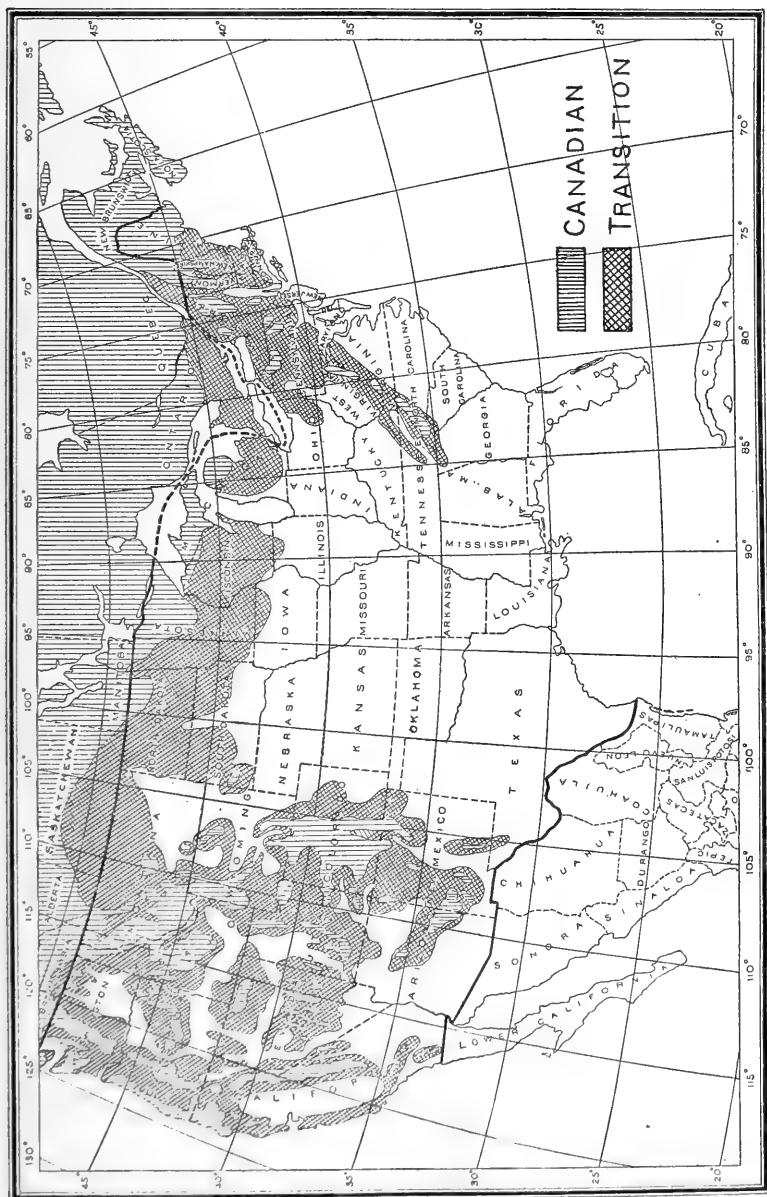


FIG. 2.—Map of life zones in which fox farming is feasible in the United States, showing the Canadian Zone, where conditions are excellent, and the Transition Zone, in parts of which conditions are favorable.

the Biological Survey show that such localities occur only north of the southern boundary of the Canadian Zone. This boundary, as shown on the accompanying map (fig. 2), crosses the States of Maine, New Hampshire, Vermont, Michigan, Wisconsin, Minnesota, and

North Dakota, and extends southward along the mountains in New York, Pennsylvania, West Virginia, and in all the States of the Rocky Mountain region and westward. South of the forested regions of the northern tier of States and western Oregon, however, the Canadian Zone, although sufficiently cold, is too dry and sunny for the production of first-class fur. In the Transition Zone, foxes having a fair quality of fur may be raised, but the best are obtained only in more northern latitudes.

RANCH SITES.

One of the most important conditions affecting the choice of site for a fox ranch is security from unusual noises and occurrences. Not that the animals must be kept where they can neither see nor hear the

doings of civilization; but these must not be irregular or obtrusive, and every precaution should be taken to prevent unusual disturbances. The fox is naturally timid and nervous. It can be tamed to a degree, but its excitable temperament can be completely overcome only by a long process of careful breeding and selection. It is especially shy and irritable during the breeding season.

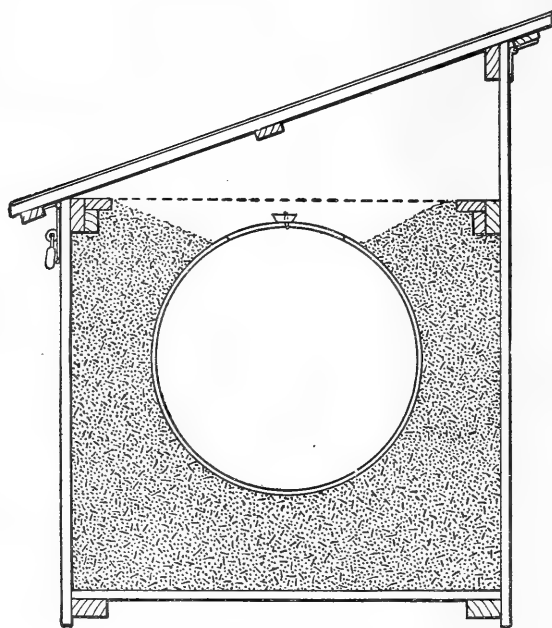


FIG. 3.—Vertical cross section of a barrel den.

Foxes like to be screened from observation, and by day

in the wild state are rarely found far from cover. During the heat of summer, especially, they enjoy dense shade. Furthermore, sunshine is deleterious to the color and character of fur. It is advisable, therefore, to locate a ranch among a growth of young trees thick enough to shade about half of the ground. Deciduous trees are preferable to evergreens, as they allow the sun to make the yards more comfortable in winter and to clear the ground of snow earlier in spring. Old trees are likely to be broken by storms, and in falling to demolish fences.

On a slope with a southern exposure the snow will be gone and the ground warm when the cubs are ready to leave the dens. A clay

surface is to be avoided, but a subsoil of clay or hardpan is an advantage, as foxes will not dig ground hard enough to require a pick to break it up. Gravel affords excellent drainage, but foxes burrow deeply in it and thus are difficult to manage, even though they may not escape.

INCLOSURES.

A model fox ranch has three kinds of inclosures: Dens, where the animals are sheltered and in which the young are born; yards or runs, where they may have sunshine and shade and sufficient exercise to keep them in good health; and a guard fence surrounding the entire ranch, for the double purpose of preventing intrusion from without and escape from within.

DENS.

The walls of a fox den should exclude moisture, deaden sounds, and protect the occupants from extremes of heat and cold. During the

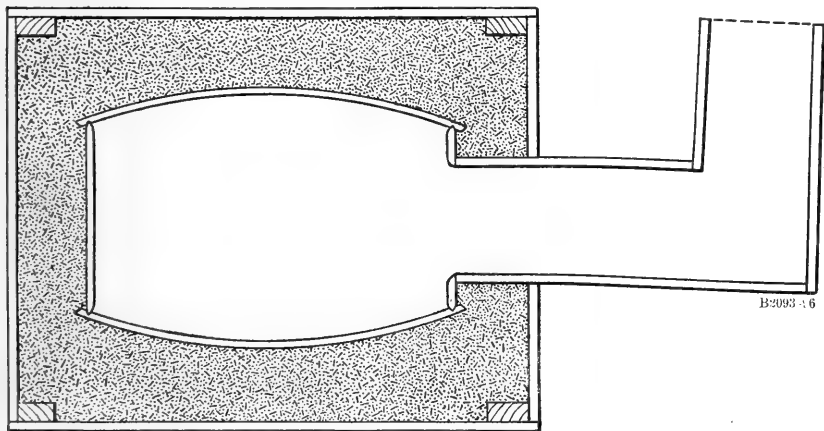


FIG. 4.—Horizontal longitudinal section of barrel den.

breeding season, when foxes are unusually nervous, and when the cubs can not withstand exposure, these features are particularly important. Provision should also be made for ventilation without admitting light or drafts. The barrel den shown in figures 3 to 6 is merely a clean barrel, having a smooth interior, surrounded by dry sawdust, within a wooden box. In one head of the barrel is an entrance hole 8 inches wide and 10 inches high. A similar opening is made in the upper side for inspection, cleaning, and ventilating. Above the barrel a screen door is hinged to preclude escape when the cover is raised. A sheet of burlap tacked to one side of the screen-door frame and spread over the netting when the covers are raised for ventilation will keep out air currents and light. At the entrance hole is an elbowed spout, $2\frac{1}{2}$ feet in the shorter arm and 6 feet in the longer.

The large den shown in figures 7 to 9 has advantages not found in barrel dens. It has double walls, the interspaces being lined with building paper and filled with sawdust. The exterior may be batted, shingled, or covered with tarred paper. It is large enough to give the foxes lounging room outside the nest compartment, and is arranged so as to be easily cleaned and disinfected. By leaving the door open on fine days, the interior can be exposed to the drying and purifying effects of sunshine. The door and the opening to the exit chute should face southward, and the rear end should be raised enough to give the floor a slant downward toward the door. The

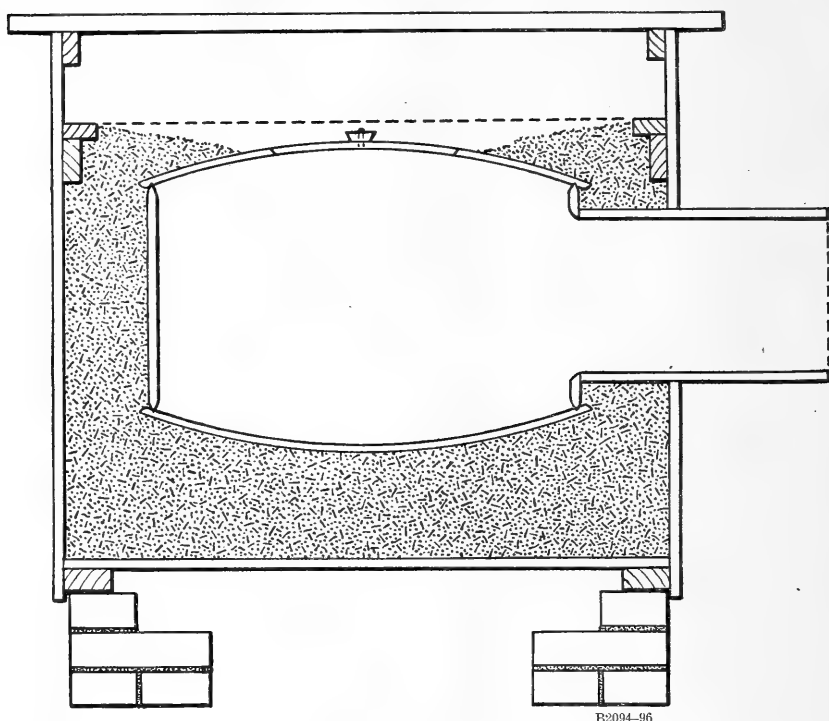


FIG. 5.—Vertical longitudinal section of barrel den.

entrance to the nest compartment and the inner end of the chute should be about 4 inches above the floor to prevent the cubs' getting out before they are able to return.

The corners around the floor of the nest compartment are filled with a chamfered strip of board (figs. 7 and 8) to keep very young cubs in contact with the vixen and thus prevent their becoming chilled. To accommodate a large family of cubs running about the yard, it is advisable to have extra dens improvised from barrels or boxes, as shown in figures 10 and 11. Such shelters increase the diversity of the yard, and afford the animals a choice when seeking protection from the weather. As to the proper location of a den, opinions differ.

Some place it near the middle of the yard, where the foxes are supposed to feel more secure. Others locate it outside the yard, in order that the vixen may not jump to and from the roof and thus cause abortion. All dens placed outside of yards should have an inner door of wire netting if they open to an alley.

YARDS.

Although fox yards vary in size, shape, and construction, depending on conditions on different ranches, there is a definite type now generally recognized as best adapted to fox farming. Such a yard has an area of from 2,000 to 2,500 square feet. The majority in the recently built ranches are 50 feet square. Some breeders prefer long, narrow yards, which give the foxes more space for a hard run when they are frolicsome, though the cost of fence materials is considerably greater than for square yards of the same area. The arrangement of a series of yards depends upon the space they are to occupy.

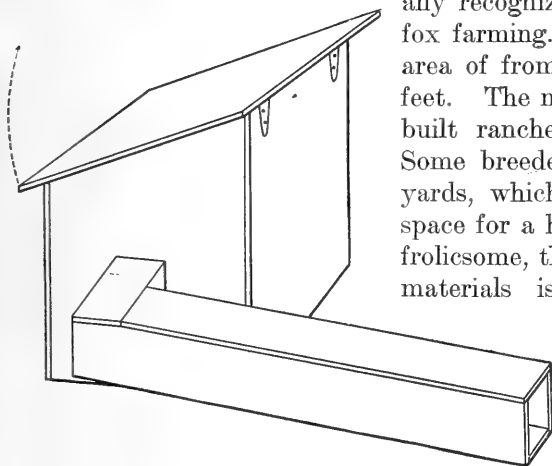


FIG. 6.—Exterior view of a barrel den (see figs. 3-5).

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When arranged as nearly as possible in the form of a square the expense of inclosing by a guard fence is less than when side by side in a row. Two plans of four-yard ranches are shown in figures 13 and 14, the smaller compartments being for males. The expense for posts and scantlings in building a ranch on the plan of figure 13 is less than for the plan of figure 14, inasmuch as adjacent yards have a common frame between them. But the extra cost of building detached pens as shown in figure 14 is more than compensated for by the greater convenience in caring for the animals and in controlling them in case they escape from their yards. If a fox gets out of its yard, it is sure to be discovered in one of the alleys, whence its return to its proper quarters is a simple matter.

The supports of a fence are ordinary wooden posts set in the ground at intervals of from 12 to 16 feet. The heaving effect of frost, however, has caused many fox owners to abandon them for a framework of scantlings entirely above ground. The foundation may be of stone, concrete, or creosoted planks. The posts of framed fences are tied together by the netting and braced from the ground as shown in figure 15. A durable and attractive fence support

recently adopted by several fox owners is shown in figure 16. It has a concrete foundation 4 feet deep, 9 inches thick at the bottom, and 6 inches thick at the top, and projects slightly aboveground. In this are embedded posts of 1-inch galvanized-iron pipe. Tie-rails of $\frac{3}{4}$ -inch pipe connect these posts at the top and also just above the foundation.

Wire netting for fox-yard fences has been in use from the beginning. It allows free circulation of air and permits the animals to take an active interest in their surroundings and in one another. The netting ordinarily used is like that for poultry runs, except that the wire is heavier. It may be of 2-inch mesh in 14, 15, and 16

gauge. The lower part of a fence should be made of the heaviest wire obtainable, the lighter grades being used for the middle and upper parts. As very young foxes are likely to become entangled in 2-inch netting or even to go through it, many fox breeders use only $1\frac{1}{2}$ -inch mesh. Those having 2-inch mesh usually reinforce it from 6 inches

above the surface of the ground to 6 inches below it with boards or a strip of 1-inch netting.

The disposition of foxes to take an adversary at a disadvantage has led to serious injuries when adjoining yards were separated by only a single partition of coarse netting. In a number of instances a climbing animal has had its foot seized, pulled through the fence, and held by the occupant of the next yard until its frantic struggles to escape resulted in a badly mangled leg. Such accidents can be avoided by making double-walled partitions, the walls separated by at least

4 inches, or single-walled partitions of 1-inch netting or of boards. The necessity of erecting double partitions is overcome, however, by use of the plan illustrated in figure 14.

The height of a fence depends somewhat upon the depth of the snowfall. In Maine and the Maritime Provinces the usual height is 9 or 10 feet, while in Labrador it is 12 feet. To prevent foxes from

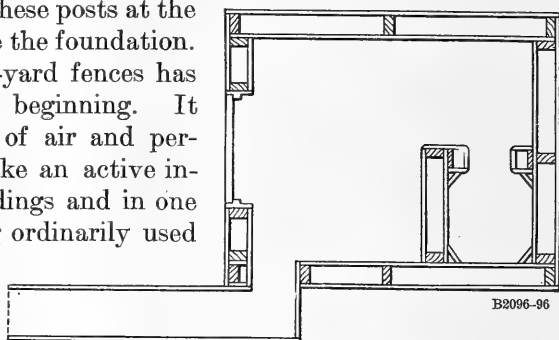


FIG. 7.—Ground plan of a double-walled den.

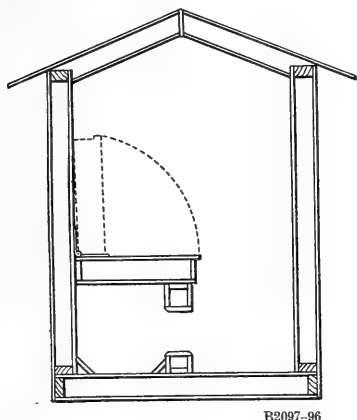


FIG. 8.—Vertical cross section of double-walled den.

digging out, the fence is either extended into the ground (fig. 17) or turned abruptly inward at the surface (fig. 18) to form a mat 3 feet wide, the inner edge of which is pinned firmly to the ground and usually covered with earth or stone. A fence extended into the ground must reach a depth of 4 or 5 feet if the soil is soft, and be turned inward a foot at the bottom. If there is a subsoil of clay or

hardpan, the fence need not enter it more than 6 inches.

Instead of netting, the underground part of a fence may be made of 2-inch creosoted planks. As foxes climb wire

fences readily an inward overhang about 18 inches wide should be placed at the top to prevent escape (figs. 15-20). When a fox has scrambled up to an overhang, its only means of descending is by falling.

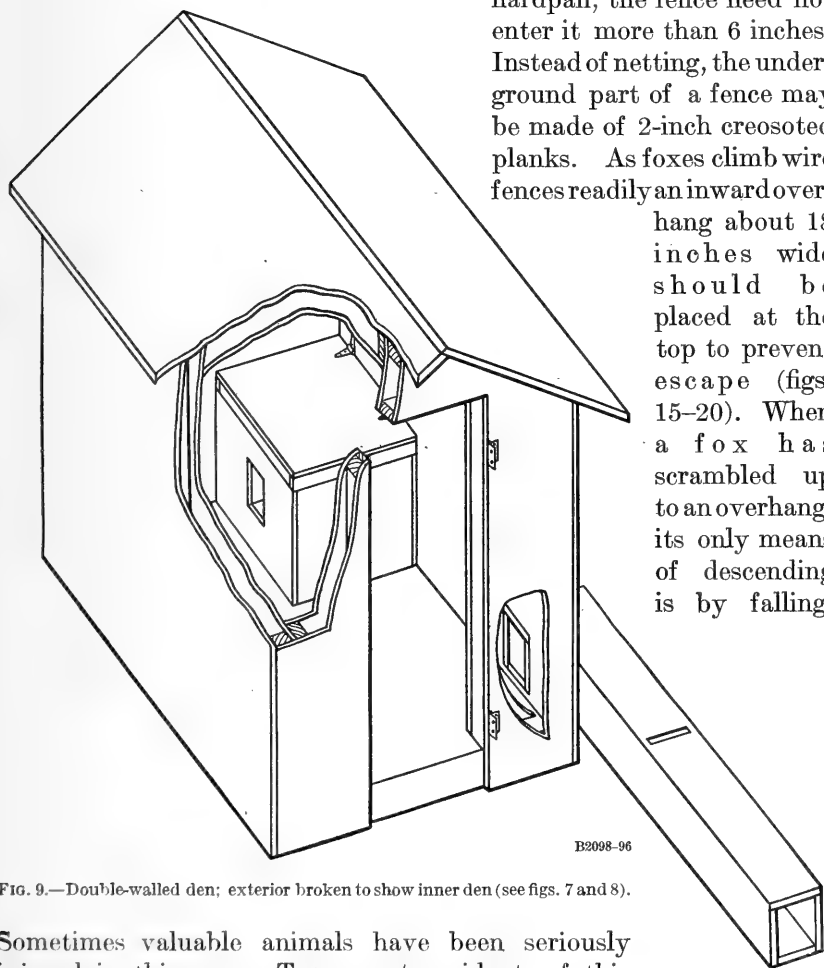


FIG. 9.—Double-walled den; exterior broken to show inner den (see figs. 7 and 8).

Sometimes valuable animals have been seriously injured in this way. To prevent accidents of this kind an intermediate overhang is sometimes constructed 5 feet from the ground, as shown in figure 16, or a smooth zone of boards or sheet iron is inserted in the upper half of the fence, as shown in figure 20.

The yards for sequestering males are usually adjacent to the main yards, with which they are connected by a chute having a sliding door (fig. 21), though sometimes they are separated from the family

yards. It is advisable to have them roomy, as indicated in figures 13 and 14, in order to give the animals enough runway to make them vigorous during exile. When allowed to be together the pair may have the run of both yards. Although quarters for constant occupancy should be roomy, those for temporary use, such as are required by dealers and by ranchmen for isolating sick or newly arrived animals, may be comparatively small. Temporary pens are often

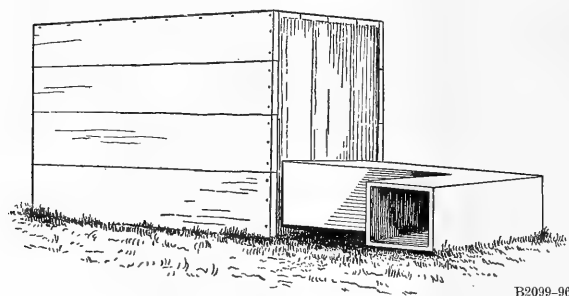


FIG. 10.—Den improvised from a box.

not more than 6 by 10 feet on the ground and 4 or 5 feet high. They are made with netting on top, bottom, and sides, stretched over a frame of scantlings. The posts do not enter the ground, but rest upon sills, to which they are securely

nailed. By means of braces the frame can be made rigid, and when covered with netting is strong enough to be moved without weakening. The cheapness, security, and portability of these pens make them a very useful adjunct. Foxes have bred and reared young in temporary pens that were only 12 by 15 feet, but such narrow quarters are not recommended for permanent use.

When alleys are used between pens, as shown in figure 14, it is well to have them closed at the outer ends to facilitate the return of escaped animals and provided with overhangs. Entrance to the yards should be by way of these alleys.

Doors may be made entirely of wood, or of netting attached to a durable frame which can not be gnawed by a fox or warped (fig. 19). If they are divided into upper and lower sections of equal size, much of the labor of clearing paths when snow is deep can be eliminated by leaving the lower half of each door closed.

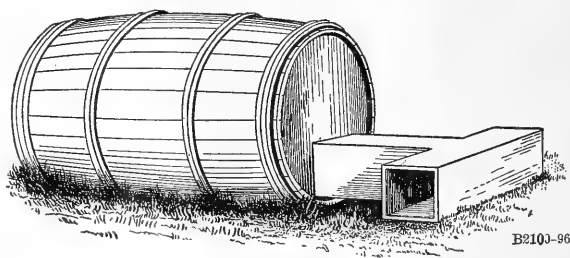
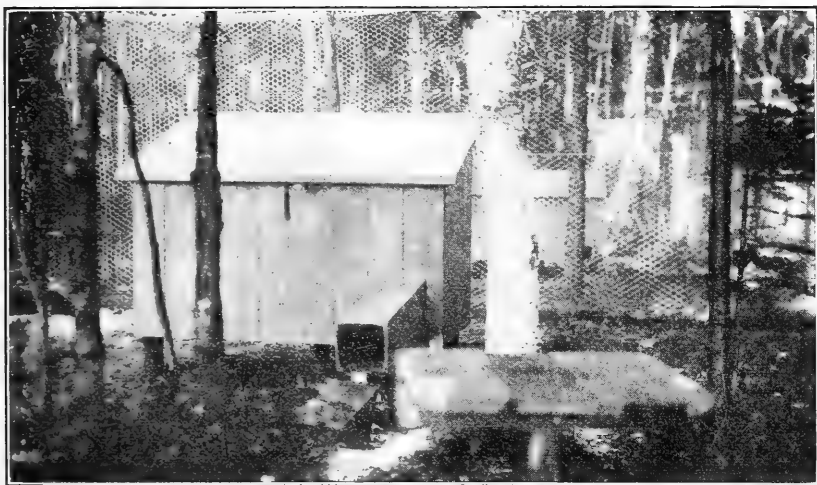


FIG. 11.—Den improvised from a barrel.

GUARD FENCES.

The guard fence surrounding a fox ranch is generally constructed like the yard fences already described. Where snow drifts badly, the fence should be built of boards rather than netting, in order to keep the snow from piling up in the yards. In addition to the usual

inward overhang it should have an outward overhang of barbed wire to keep out dogs and other intruders (fig. 15).



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FIG. 12.—An inexpensive type of den. Table in foreground is for the food of parent foxes; by means of it young cubs are prevented from obtaining too much meat.

FOOD.

Wild foxes eat a wide variety of food, including mice, rabbits, birds, insects, and wild fruits. When grasshoppers are present large quantities are eaten. Meat, therefore, is only a part of their natural diet.

Indeed, foxes, like dogs, are almost omnivorous, and there is less danger in feeding any particular kind of food than in feeding too large quantities at irregular intervals.

The rations of domesticated foxes include beef, horse meat, mutton, veal, woodchucks, rabbits, liver, fish, eggs, milk, bread, mashed potatoes, crackers, mush, dog biscuits, and soft fruits. The selection

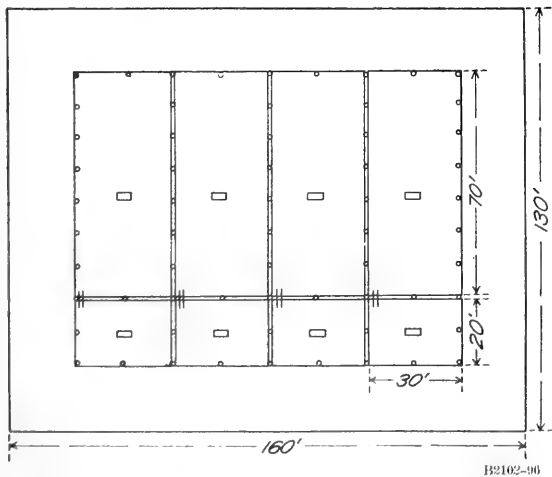


FIG. 13.—Plan for rectangular yards in series; dens within yards.

of meats is largely a matter of circumstances. At irregular and uncertain intervals one may obtain injured or worn-out but otherwise

healthy horses, old sheep that can not be fattened for mutton, all of which, when slaughtered, make good and cheap meat. Wherever available, whale meat is used extensively. Woodchucks and rabbits, freshly killed, are always welcome in a fox yard. When cheap meats fail, beef and poultry are used.

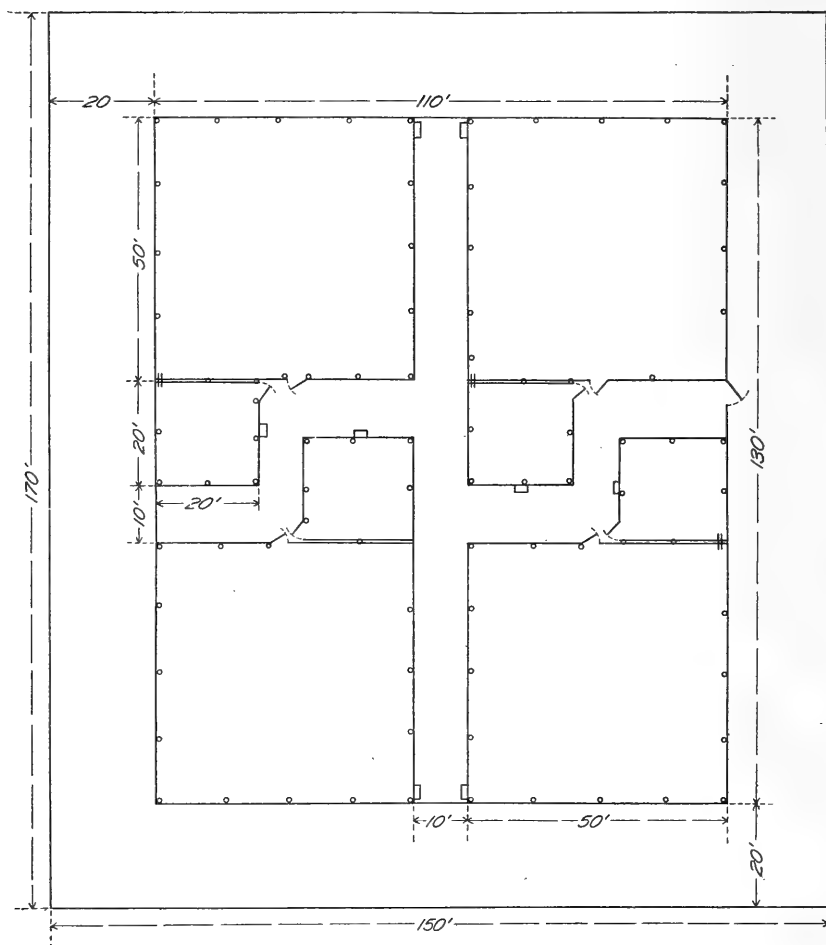


FIG. 14.—Plan for square detached yards; dens and doors in alleys.

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Fortunately, foxes do not need meat every day. Some keepers feed it but two or three times a week. Young foxes are not allowed meat until they are four months old, as it is likely to cause rickets. Milk, with some sort of bread or cooked mush, is the standard food for old and young. Foxes which are fed twice a day usually have meat in the morning and bread or mush and milk at night. In summer the proportion of meat is less than in winter. When smelts or trout can be had they are frequently substituted, but fish is not considered

good for foxes in warm weather. Coarser fishes are sometimes used, but are not very much in favor. It is not deemed well to feed milk and fish on the same day. Milk and eggs are often given to females about the time cubs are expected, to strengthen them, relax their bowels, and allay fever. Fish, liver, and tripe are other laxative foods which may be used instead of milk and eggs. A diet of eggs, milk, mush, and wheat bread without leaven or salt is excellent.

The preparation of food for foxes deserves careful attention. All dishes should be kept clean. Meat that is diseased, tainted, or infected with parasites must be boiled. It is better to skin rabbits, as their hair readily

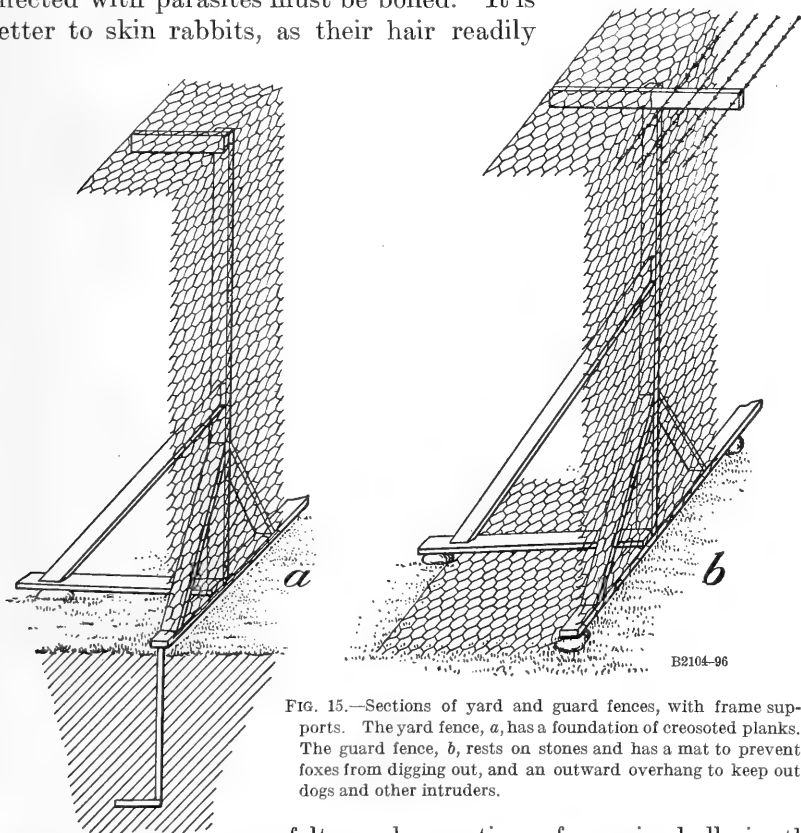


FIG. 15.—Sections of yard and guard fences, with frame supports. The yard fence, *a*, has a foundation of creosoted planks. The guard fence, *b*, rests on stones and has a mat to prevent foxes from digging out, and an outward overhang to keep out dogs and other intruders.

felts and sometimes forms in balls in the stomachs of animals which feed on them. Their heads and entrails also should be removed, as these parts are frequently infested with parasites. Smelts and small trout may be fed whole, but larger fish should be dressed and the backbones removed. Chilled meat should be warmed before being offered to cubs or nursing females. Oatmeal or cornmeal mush should be thoroughly cooked. All food for sick animals should be cooked to make it more digestible and to free it from disease germs.

Foxes should be fed regularly twice a day, morning and evening. This is especially important in hot weather, as whatever is left from the first meal will spoil before time for the next. By giving at each feeding only the proper quantity, the injurious effects of gorging can be avoided. Overfeeding is more dangerous than underfeeding. Fat animals are not prolific breeders. Eight or ten ounces of meat is sufficient for one meal.

BREEDING.

Foxes breed only once a year, the mating season occurring in February or March, and lasting anywhere from a few hours to two

or three days; it is often indicated by a brownish discharge. The period of gestation is about 51 days, the young being born in April or May. The number of young in a litter varies from two to eight, the average number born to adult parents being four. In the wild state foxes are monogamous, and while the young are being reared the male dutifully forages for them. In captivity, however, one male sometimes has been mated successfully with two or even three females. In certain cases this may be desirable, but very often it results

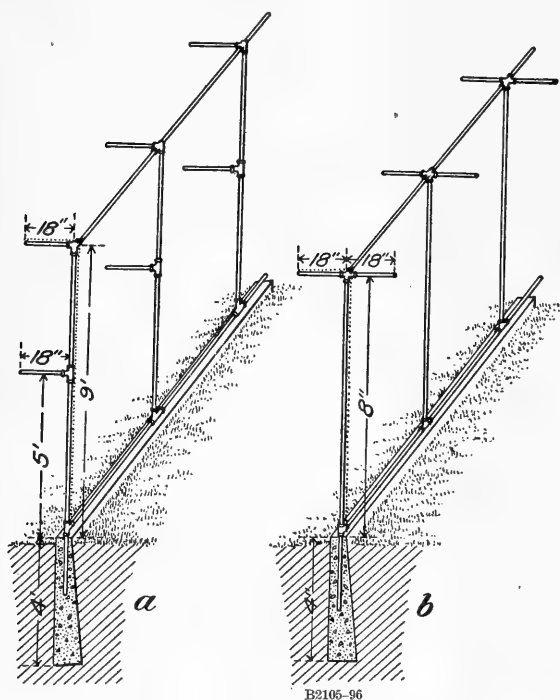


FIG. 16.—Iron posts and concrete foundations for yard fence, *a*, and guard fence, *b*. Note the 18-inch overhangs, two on the yard fence, one of which (5 feet from the ground) is to prevent foxes from climbing to the top and the resulting injury from the greater fall.

in no increase whatever. Breeders generally prefer to keep their foxes in pairs.

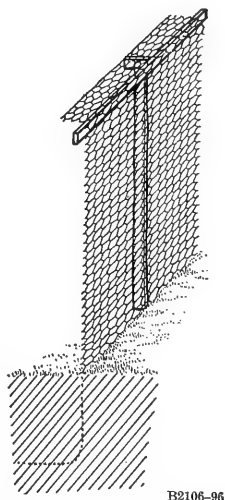
Males are removed from the breeding yards for a part of each year, the length of their exile depending upon the relations of the pair. If they are quarrelsome, it is best to separate them soon after the female becomes pregnant. If, on the contrary, they agree and show attachment to each other, it is wise to keep them together until the cubs are four weeks old, but after that the male is likely to bite them during scrambles for food at meal times. While the vixen is devoting

herself to the young, the male carries food to her and warns her by sharp barks whenever he suspects danger. While sequestered, the males are usually kept in small pens which may adjoin the breeding yards, as shown in figures 13 and 14, or removed to a separate inclosure, where they may be allowed to run together in a large yard or confined in individual pens. Because of their inclination to fight, individual pens are preferable.

The reproductive period in foxes is about 10 years. Approximately 50 per cent of the females in domestication breed each year, and the aggregate increase is not far from 100 per cent for the total stock on ranches. Failure to breed is attributable to a variety of causes, among which are sterility, injuries, worry, and mismating. Females barren for two years in succession frequently become productive on being mated to a different male. Prolific vixens, run down by several litters in succession, sometimes skip a year in which to recuperate. Foxes breed more freely on the ranch where they were reared than amid strange surroundings. Their wild nature dominates most of their actions. They are constantly in a state of apprehension, and it is only by the greatest care that confidential relations can be established between them and their keepers. This

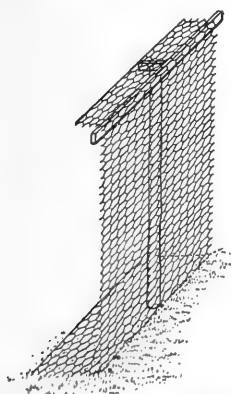
fear may cause the female to refuse the attentions of the male; or she may become excited so as to injure herself and give birth prematurely. But worst of all, even after producing a litter of healthy young, she may be so solicitous for their safety as to maltreat or kill them in her efforts to get them out of imaginary harm's way. Often when her young are just born, or only a few days old, she will carry them about the inclosure all day, apparently seeking a place to hide them. Perhaps she digs a hole in the ground and removes them one by one from the warm den to the cold earth. Thus the little things may be moved successively to a number of freshly dug holes and to and from these and the den until they die. From the time the cubs are born until they are two or three weeks old

constant care must be taken to prevent losses in this manner. Any unusual sight, sound, or odor, by day or night, is liable to alarm a vixen and cause her to maltreat her young. The best way of dealing with a worried vixen is to shut her with her cubs in the den for several



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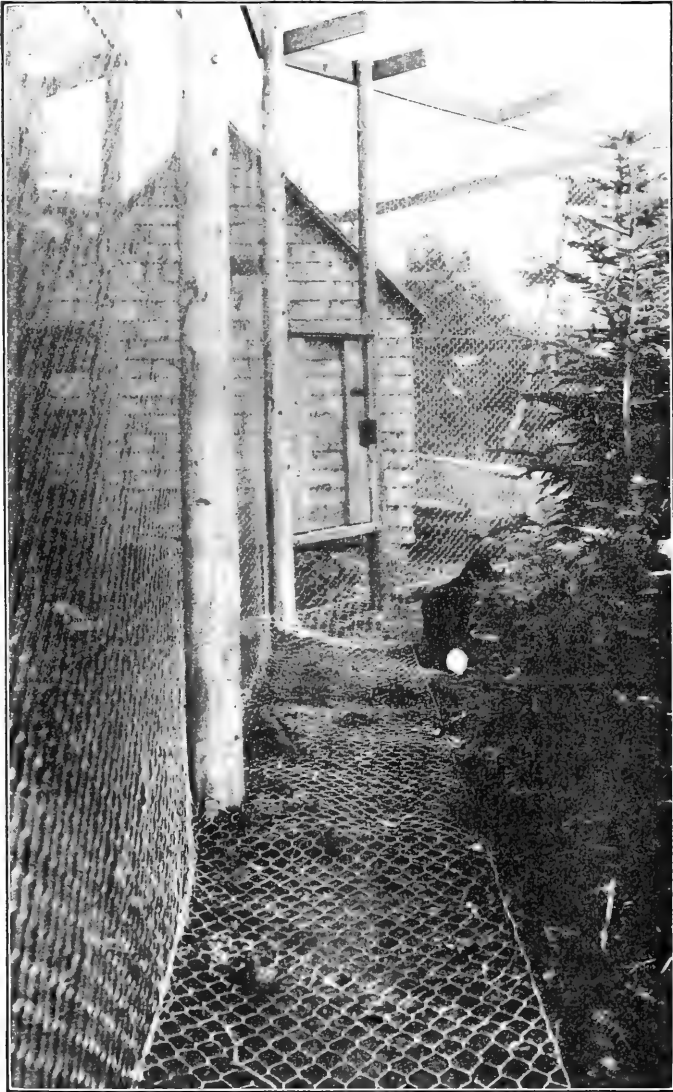
FIG. 17.—Fence extending into the ground.



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FIG. 18.—Fence turned inward at surface of ground to form a mat.

hours or until she becomes pacified. If she is disturbed by the proximity of other foxes, as sometimes happens, her view should be limited by boarding in the lower 2 or 3 feet of her yard.



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FIG. 19.—Details of entrance, mat, and overhang of a fox yard.

CARE OF YOUNG.

Young foxes are subject to other troubles which, unless corrected, often prove fatal. They may be infested with external or internal parasites, or their mothers may not have enough milk to nourish

them properly. It is very important that their condition from day to day be known. But the great value of the cubs, and their danger from the irritability of their mothers, generally cause the keeper to refrain from looking into the dens. By watching the behavior of the mothers they judge whether or not the young are doing well. It has been demonstrated by at least one progressive keeper that this uncertainty is by no means necessary. Foxes are not excited by routine events. By giving them large two-room dens, similar to the one shown in figure 9, and always feeding them in the outer compartment, they are led to expect the entrance of the keeper as the regular preliminary to each meal, and even to welcome it. When the keeper enters, they, of course, depart, leaving him free to look into the inner den. He should not touch the cubs unless they need attention.

The young are small and weak at first, and their mother remains with them almost constantly for the first three days. They grow rapidly and usually begin to appear outside the den in about a month. When 6 weeks old they eat more or less solid food. After this they may be weaned. Many breeders leave the weaning entirely to the vixen unless she is becoming emaciated. A decided advantage in weaning cubs when they are 6 or 8 weeks old is that when the keeper controls their food he can more easily eradicate the intestinal worms which usually infest them. Care should be taken to keep early-weaned cubs clean and dry. In case of accident to a mother fox, cubs may be reared by cats almost from birth. Not more than two cubs should be given to one cat. After they are about 3 weeks old their teeth become large and sharp enough to lacerate their foster mothers, and they must be reared by hand.

BEHAVIOR IN CAPTIVITY.

Aside from propagation, the domestication of foxes has proved simple. It is true that they rarely become very tame. Even after several generations of parents reared in captivity the offspring retain the wildness characteristic of the species. Nevertheless they are amenable to gentleness. They quickly learn to recognize their keeper and to come to the feeding place when called. Most of them can be induced to take food from the hand, but their tempers are uncertain.

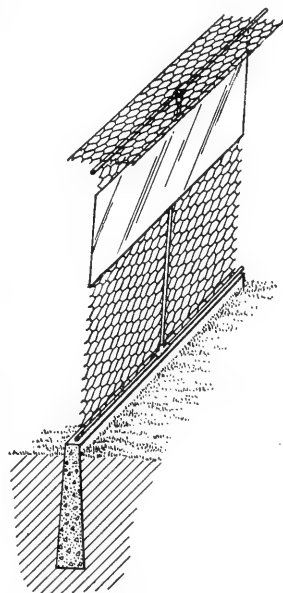


FIG. 20.—Section of a fence containing a smooth zone to protect foxes from injury by falling. Concrete foundation and iron posts.

Instinctively timid and distrustful, unlike dogs, they do not seem capable of becoming attached to the person in charge of them. The approach of a stranger makes them uneasy and usually drives them into their dens, but ordinary travel along a thoroughfare a hundred yards or more away gives them no apparent concern. All moving objects interest them keenly. Birds alighting within their yards often fall prey to their agility. If well fed they seldom fight, and when they do, fatalities rarely result. In a few cases two or more have turned upon another and killed or badly crippled it, but usually this has been due to underfeeding or to improper handling during the mating season. When believing themselves unobserved, they play together or lie contentedly stretched at length in the sun.

Cold weather has no terrors for foxes, and snow is a delight. At times of alternate freezing and thawing they should not be allowed to

lie down on snow as they may thus seriously injure their coats. They rarely make determined efforts to escape from inclosures except during the first few days of captivity. Then they dig for perhaps a foot at the extreme edge of the inclosure where the wire enters the ground, but if the wire is merely turned in at the bottom (fig. 18) they dig only in the angle, and obviously can not accomplish much, as they must work by thrusting their paws through the meshes. If stones are placed along the edge of the wire, foxes make no effort to dig out, as tunneling under seems never to occur to them. The

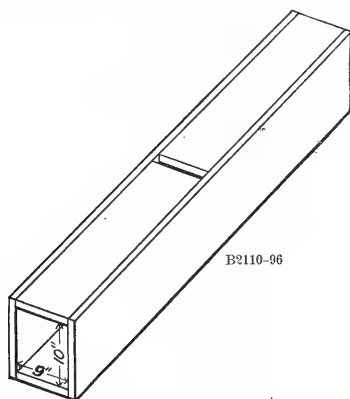


FIG. 21.—Chute for connecting yards. It can be closed by inserting a sliding door in the slot.

overhang at the top of the fence ordinarily prevents escape in that direction, but an unusually heavy fall of snow sometimes enables foxes to reach an elevation from which they can leap upon the overhang and scramble out. In several cases, however, they have returned to the inclosures and climbed back or have been caught in traps set for them near by. When at large, foxes do not often climb trees, but in captivity they do so readily, often lying for hours curled up in the thick branches of a spruce or fir.

HANDLING FOXES.

Unless foxes are diseased or injured, it is rarely necessary to lay hands on them. When one is to be removed from its yard, ordinarily it can be first driven into its den and thence into a small handling box having a sliding door at one end and strong wire netting covering one side. In this manner it can be transferred without

danger of injury to itself or its keeper. It is best to darken the handling box by covering it or by turning the netted side downward on the ground before attempting to drive a fox into it. In actually handling grown foxes it is prudent to wear gloves to guard against being bitten, though this precaution is not always adopted by experienced keepers who understand just how to handle them. An effective device for catching foxes is a pair of tongs with jaws curved to form a circle $2\frac{1}{2}$ inches in diameter. The fox is first driven into its den or into a large covered box. Then the cover is raised barely enough to let the tongs pass in and grasp the fox around the neck. By holding the tongs in one hand and grasping the hind feet and tail of the fox with the other, the animal can be held securely.

Healthy foxes if properly boxed and cared for can be shipped safely almost any distance. Two foxes or even more than two are sometimes shipped in the same compartment, but this is inadvisable unless the distance is short. As a rule, a box containing two should be partitioned, each animal having a space equivalent to 2 by 3 feet on the floor and $1\frac{1}{2}$ feet high. About half of one side of the box should be removed and the opening covered with wire netting to allow ventilation and inspection. Shippers often cover the entire box with netting or tin to preclude the possibility of escape. A dish for water should be fastened to the floor close to the front, where it can easily be filled. Foxes are not usually injured by a fast of three or four days but they should not be allowed to suffer from thirst. Express companies, if duly instructed, will feed animals en route and add the cost to the regular transportation charge. In case the animals are very valuable or are to be shipped a long distance, an attendant should accompany them.

SANITATION.

Generally speaking, sickness is not common among domesticated foxes that are well cared for. Once in a while one breaks a leg as the result of a fall or, more often, from entanglement in wire netting having too coarse meshes. Lacerations rarely result twice from the same cause or from fighting. Even more rarely a fox is choked while eating. Passing meat and small or soft bones and cartilage through a bone grinder will not only prevent choking, but allow enough bone to be fed with the meat to produce sturdy animals. Simple fractures, uncomplicated by abrasions, will mend if untouched, but it is better to bind splints upon the wounded limb to keep it in proper shape, and then to apply iodoform to prevent the animal from tearing them off. When a bone is badly shattered, and especially when it protrudes, the leg should be amputated. Anesthetics are likely to kill foxes and hence should not be used. Flesh wounds ordinarily require no attention other than washing once or twice a day in warm

carbolated water or with castile soap, followed by an application of hydrogen peroxide.

Thus far no widespread disease among foxes has made its appearance. When diseases occur they mainly affect the digestive organs, and usually can be traced to improper feeding. Indigestion and inflammation of the bowels are not uncommon among cubs. Isolation in clean, dry quarters is the first step toward a cure, and rest and fasting are better than medicine. A spoonful of milk diluted with six spoonfuls of boiled water will quench thirst and aid in maintaining strength. The feces should be examined daily. Constipation is frequent, and it is especially dangerous to vixens during the first three days after the birth of their cubs. It can generally be corrected by a laxative diet, as milk, liver, or veal, but in extreme cases a dose of castor oil or an injection of soapsuds may be necessary. A protracted attack of diarrhea can usually be checked by a purge of castor oil followed by small doses of laudanum. Generally, however, a day or two of fasting followed by short rations of cooked milk or milk and eggs, at intervals of two or three hours, will effect a cure. During such an attack vitality runs low, and care must be taken to keep the afflicted animal in a warm, dry place. It should have access to water that has been boiled. Growing cubs are frequently subject to weakened and distorted legs. This disease, known as rickets, can be prevented by including ground bone in their meat rations and by adding limewater to their milk. The bones of calves and those from the briskets of beeves are comparatively easy to crush so that foxes can swallow them.

At quarantine stations, where imported animals are examined, particular attention is directed to symptoms of rabies and mange. The fact that rabies, or hydrophobia, is communicable to man makes it doubly dreaded. Fortunately it has not appeared among domesticated foxes so far as known. Mange is characterized by a loss of fur. It is caused by a tiny parasite, somewhat like the itch mite, and is, therefore, very contagious. Were it to obtain a foothold among domesticated foxes, it would seriously hamper and perhaps ruin this branch of the fur industry. All animals showing a tendency to have bare spots should be isolated at once. The diseased parts should be treated daily with ointments, as petrolatum or a mixture of lard and sulphur.

Foxes serve as hosts for a number of other parasites. Lice and fleas infest their hair and skin, while roundworms and tapeworms drain their vitality from within. The death of a fox has occasionally been attributed to lice. Even if not fatal, lice and fleas diminish the vigor of their hosts and should be persistently combated. Some fox breeders dip all their animals in a solution of creolin or a similar nonpoisonous dip shortly after the cubs are weaned. It is well in

any case to dust the dens with sulphur and insect powder at frequent intervals.

The intestinal worms infesting foxes are difficult to eradicate. Probably more young foxes succumb to the effects of roundworms than to any other cause. These worms are whitish, cylindrical creatures, tapering toward either extremity. Among the symptoms indicating their presence are dullness, barking, frothing at the mouth, dragging the body by the fore legs, and convulsions. The flat, jointed tapeworm, often a foot or more in length, is a less fatal as well as a less common internal parasite, but animals suffering from them are emaciated and lack overfur or guard hairs. As a cure for worms one breeder of long experience frequently gives his cubs a meal of crushed flaxseed and milk, alternating now and then with six or eight drops of spirits of turpentine in milk. Another doses his cubs every fortnight after they are four weeks old with a proprietary vermifuge put up in gelatine capsules for puppies and pet dogs, beginning with half of the contents of one capsule. Castor oil containing a few drops of turpentine is also recommended. Any remedy administered by hand must be pushed down below the base of the tongue, when it will be involuntarily swallowed.

A fox sometimes dies from no assignable cause. More often fatalities can be traced to a lack of care or foresight. The dishes from which the animals eat and drink should be washed daily and scalded frequently. The water should be clean and changed daily. The food should be varied and wholesome. Danger from unwholesome food is well illustrated in the experience of one ranchman who lost several of his choice breeders through feeding them spoiled fish; and another who lost \$100,000 worth of cubs as a result of thoughtlessly exposing meat overnight to the fumes of gasoline in his slaughterhouse. The appearance of each animal should be critically noted every day. On many of the larger ranches a doctor is regularly employed to look after the health of the stock. In the care of foxes an ounce of prevention is worth a pound of cure.

IMPROVED STRAINS.

The fact that domestic animals originated from wild stock and that improved strains have from time to time been secured makes it reasonable to assume that other wild animals can be differentiated and improved by the same method, namely, selective breeding. So far as foxes are concerned, this has already been done. The pioneer fox breeders began with ordinary silvers, which have a tendency to produce red as well as silver progeny. At that time dark pelts were more valuable than light-colored ones. By regularly disposing of the less desirable cubs and breeding only from the best, the tendency to throw red was soon eliminated, and the color of the

fur greatly improved. Within 16 years from the time the two pioneer fox-breeders built their ranch, they were sending to market the finest fox pelts in the world.

The tendency of wild silvers to produce red progeny is accounted for by the fact that owing to their scarcity probably only one in a hundred can have a silver mate; perhaps three in a hundred may mate with cross foxes, which are merely hybrids, or descendants from hybrids, between silvers and reds; and the remaining ninety-six must mate with reds. In any event, although some of the cubs may be silver, all of them will inherit from their red ancestors a tendency to throw red. As has already been pointed out, however, this tendency very soon disappears under the influence of careful breeding. Generally speaking, pure strains of silver foxes breed true. So also do pure strains of red. When a red and silver are mated together, the color of the progeny can not be foretold. The cubs may be red with black throats, or they may be crosses, or a mixture of the two. One or more may be silver, but this is unusual. Random breeding from silvers and crosses of unknown pedigree is equally uncertain, as is shown by the following results:

A silver mated with a red produced two crosses, which when mated together produced one red and four silvers. A silver and a cross produced three silvers and two reds. A cross and a red produced two crosses and two reds. A cross and a cross produced two silvers, two crosses, and one red. Another pair of crosses produced nine crosses. A red of silver-cross parentage mated with a red of silver parentage produced one silver and two crosses. A silver and a red produced in two successive years thirteen silvers. A pair of reds from the same litter as two silvers produced three silvers, one cross, and two reds. A pair of silvers produced one silver and five reds, two of which, when mated together, produced three silvers and one red the first year and two silvers the next year. Another pair of silvers produced four crosses; while a silver and a cross produced a litter of all silvers.

These results indicate the uncertainty of breeding at random, but they show also that if a fox of any color whatever has in his veins silver blood, the silver can be made to appear in succeeding generations by selective breeding. This fact is most important. Suppose a breeder has a strain of silvers lacking in size, or fecundity, or in some other desirable particular. He can introduce specimens having the desired qualities without having to consider color. A red fox can be used if one of better color is not available. In the course of three or four generations the silver can be fully reinstated. Among the features to be considered besides color are size, fineness of fur, fecundity, docility, and hardiness. Fecundity appears to be a

hereditary trait among foxes, daughters of prolific mothers being themselves generally prolific. How rapidly other desirable characters can be incorporated remains to be determined. As with poultry, horses, and other farm animals, so is it with foxes. Each breeder should strive to perfect his animals according to some standard. Eventually there may be several standards based upon varied uses or requirements.

The process of developing improved strains can undoubtedly be shortened by taking advantage of local variations in foxes. One of the lines of investigation conducted by the Biological Survey includes the geographic variations of North American mammals, and from this it is possible to say not only where silvers and crosses occur most frequently, but where the largest and the best-furred foxes are found. Upward of 20 species or subspecies of red foxes have been named in the United States and Canada. The medium-sized foxes along the North Atlantic coast are notable for their fine silky hair. The largest foxes are in Alaska and on the Plains northward from Minnesota and North Dakota. The large size of Alaskan coast foxes is offset by long, coarse pelage, which is decidedly longer on the shoulders and back of the neck than on the back and hips. It remains to be seen whether in crossing them with the smaller, finer-haired animals the progeny will be large or small, coarse-haired or fine, or intermediates. There can be little doubt, however, that in the long run such a cross will result in larger fine-haired foxes than any now existing. The northern part of the red fox's range has, as a rule, a larger proportion of silvers than has the southern. An exception is found in the Cascade Mountains in Washington, Oregon, and California, where, judging from specimens in the National Museum, the percentage of melanistic specimens is very large. They have little to recommend them besides color, however, as they are small and have rather coarse fur.

Black and silver foxes are found in North America practically throughout the range of the red fox. The best-furred animals do not occur, however, throughout this range, but are obtained mainly in restricted areas. For instance, skins from the Tanana River district in Alaska and the adjacent part of Yukon Territory, from certain other parts of northern Canada, and from the North Atlantic coast from Maine to Labrador, including Prince Edward and other islands, are of about the same grade. This is recognized by the leading London furriers, who report that "in our opinion, fox skins from Labrador, Newfoundland, or Alaska are equal in quality to those from Prince Edward Island."

It is not known that any particular geographic race of foxes is especially characterized by fecundity or docility. These qualities

are probably individual, occurring in about the same proportion everywhere, and while of secondary importance, in the long run they are sure to be favorable to success in fox farming. Already prolific pairs bring much higher prices than those which have thrown small litters or have not been tested. Inasmuch as one of the main causes of loss among young cubs is the timidity and nervousness of vixens, the development of more docile strains will result in corresponding increase in the birth rate. Some male foxes are much better mates and sires than others. In selecting breeders the temperament of males as well as of vixens should be considered. The physical development and potency of males are also essential factors. Young males that are not strong, or not well developed when six months old are not likely to be of use in the breeding yards the first year, and should not be selected for sires.

Food is recognized as a very important element in the development of good animals. The finest specimens of domestic cattle are those which have been fed most wisely. As regards foxes, much remains to be learned concerning the effects of different rations upon such matters as potency, character of fur, and rate and limits of growth. It should be a part of every breeder's plan to discover what he can about the relative values of foods and methods of handling as influencing the process of selective breeding. Ultimate success or failure in fox farming depends largely upon the aspirations of those engaged in it. If breeders earnestly, consistently, and indefatigably endeavor to improve their stock and to produce pelts that are larger, softer, and more uniformly colored than the usual run, there can be no question as to the result. There will never come a time when an extra fine silver fox pelt will not command a good price, or when a breed producing such pelts will not be in demand.

ACCESSORIES.

Contentment and vigor of the animals within a ranch is of the utmost importance. Whatever contributes toward increasing these qualities should be incorporated if possible. It is well to test young foxes with such toys as a ball, a tin can, or a piece of woollen cloth, with a view to amusing them and exciting a spirit of playfulness. A variety of objects in which they can hide and upon which they can mount for a survey of their surroundings, as hollow logs, stumps, brush piles, or open barrels, is desirable.

While the suggestions given under this heading apply primarily to those having large capital invested in fox farming, they will also be found helpful to those operating on a small scale. The present value of silver foxes is so great that every precaution is taken to prevent accidents, sickness, or other misfortunes. Watchmen are kept on

guard day and night. The keeper's lodge is just outside the guard fence. In addition there is sometimes a tower, from the top of which a view can be had of all the yards. Here are recorded the progress of events in the breeding season; and from here quarrels, accidents, or signs of sickness can be discovered without alarming the animals. A tower 12 or 15 feet square and three stories high, fitted up as a 3-room house, would contain on the top floor the watchman's couch, chair, and field glasses, his table and writing materials; a cook stove, pantry, sink, and other kitchen appurtenances will be on the ground floor, and here food for the foxes can be conveniently prepared. Somewhere about the place there will be a medicine chest and various tools likely to be needed in an emergency.

Risk of loss by theft or escape is lessened by installing electric lights which can be turned on at any time, and an electric burglar alarm. Bulldogs are used to reenforce the night watchman; and on some ranches bloodhounds are kept for tracking thieves. Foxes that escape generally return to the vicinity of the ranch when hungry, and a number of small steel traps having the jaws wound with cloth should be kept on hand to catch them. Ranch foxes have less endurance than wild ones, and a good hound can usually overtake one after a short run. The manager of a ranch on Prince Edward Island has a hound which on several occasions has assisted in the capture of foxes without hurting them in the least. Such dogs are excellent insurance against loss by escape.

Other accessories of a fox ranch, and those most prominent, pertain to food supplies. There must be facilities for slaughtering horses, cattle, and smaller animals; an ice house and a refrigerator for keeping the meat fresh until it can be used; and conveniences for drying, smoking, and salting meat that must be kept a long time. A screened room or box is necessary to protect stored meat from flies. Cows are needed to furnish milk, an important element in the diet of domestic foxes. In a dairy region calves are disposed of when but 2 or 3 days old. At that age they are small, and their flesh is soft. Sometimes there are more of them on hand than can be used immediately. By having cows to suckle them a few weeks, the veal, improved in quality and increased in quantity, will be available when needed. Rabbits are the natural prey of wild foxes. They have an important place on a fox ranch as a fox food which can be drawn upon at any time, which is always fresh, and in such small units that ice or other preservatives are unnecessary.

Occasionally a vixen having young cubs is unable to give them proper attention. Then a foster parent must be supplied at once or the cubs will die. To provide for emergencies of this kind, every ranch should include several female cats.

COSTS.

The cost of establishing a fox ranch varies according to the materials used, transportation facilities, and the proportion of labor performed by the owner. The factory price of the netting described in the section relating to inclosures is from 1 to 2 cents a square foot, according to the mesh and size of wire, when sold in rolls containing 150 linear feet. It is manufactured in the various widths required for different parts of the fences. The cost of netting for a 2-pair ranch would thus be about \$225. The posts, sawed lumber, and miscellaneous hardware to complete the ranch might cost \$100. Ordinarily in a fur country the expense for lumber would not be great. A considerable saving can sometimes be made by building the guard fence of boards instead of netting. The average life of the netting is about 12 years, except when exposed to sea air, in which case it is only about 8 or 10 years.

Feeding a fox costs from \$5 to \$15 a year. On a farm where there are cows and where grain and vegetables can be raised it is not necessary to buy very much fox food. Except on large ranches devoted exclusively to fox raising and where a special keeper must be employed, the care of a few foxes will not entail much outlay.

The present demand for silver foxes and their relative scarcity place them, as stock, beyond reach of the ordinary purse. In determining a reasonable price for a breeding pair, there must be taken into consideration the value of the skins they may be expected to produce, the cost of annual maintenance, the probable deterioration of stock, possibility of loss through death or otherwise, and the question of reasonable profit from the young produced. There is a tendency to overestimate the value of fox skins which is well exemplified by the following: The average minimum value of a pelt, as estimated for 133 silver fox skins of all grades offered in June, 1914, at a London auction sale was about \$150, although at the sales they realized an average of only \$118 each. The fixed annual charges against a pair of silver foxes will vary with the locality and value of equipment, etc. On some ranches it has been estimated about as follows: Interest on cost of yards, \$10; depreciation of yards, \$10; food, \$20; and attendance, \$50; amounting to \$90; added to this must be a reasonable charge for interest on the original cost of the pair. Killing foxes at the age of 4 or 5 years, when their pelts are good, and breeding always from young stock may be practicable, but this point has not yet been decided. As a rule, one may expect to keep choice animals as long as they are productive; that is, about 10 years. Deterioration, therefore, on the live stock will be 10 per cent; and to this should be added 10 per cent for insurance against loss by death, escape, or theft. Prolific animals belonging to choice strains, in which a superior color and quality of fur have been fixed, are worth

for breeding purposes as much more than ordinary stock as thoroughbred horses are worth more than common horses, probably tenfold.

As has been pointed out under the subject of improved strains, crosses and reds derived from silvers throw a proportion of silver cubs. It is feasible, therefore, if one is willing to sacrifice the time required, to obtain a stock of silvers from these more common foxes, which cost comparatively little.

PROFITS.

The profits of silver-fox farming have hitherto been large. Prior to 1910 they were realized mainly from the sale of pelts. Since then they have been derived almost entirely from the sale of live foxes for breeding purposes. Values went up rapidly and profits multiplied accordingly.

The recent sharp decline in prices for breeding stock is quite certain to result in heavy loss to those who have paid dearly for a poor grade of animals, especially if they have not sufficient means to tide over the changing conditions.

The supply of silver fox pelts must always come from cold climates beyond the more thickly settled temperate regions. They are not likely, therefore, to become overabundant. Red fox skins have been coming to market for many years. Their numbers, while fluctuating considerably from year to year, have, on the whole, remained approximately constant. Their average value, however, has increased. This indicates a steady demand which may be expected to keep pace with the increase of population and wealth. But the supply from wild foxes can never be greater than it is now. Already red foxes can be raised and their pelts sold without loss, and it is altogether probable that before many years the rise in fur values and the introduction of more economical methods of ranching will result in making the raising of red foxes profitable. The superior beauty of silvers should always make them worth several times as much as reds, and many years must pass before they can become common.

PREPARATION OF SKINS.

The preparation of skins requires no special implements or preservatives. Extreme care must be taken to prevent blood from coming in contact with the fur. With this in view, the method of killing commonly adopted is to lay the fox on its side on clean snow, and then to compress its chest by standing upon it. This stops the action of the heart and lungs and death follows immediately. The same result, without the unpleasant features connected with thus catching and smothering the animal, can be obtained by means of a killing box which, from a humanitarian point of view, is preferable. This is merely a tight wooden box into which the fox is to

be driven from its den. When the fox is inside and the door securely closed, an ounce or two of chloroform or carbon bisulphide is poured through a hole in one of the upper corners into a wide, shallow dish, as a tin pie plate, fixed just below in such a manner that the fox can neither get into it nor upset it. The hole through which the pouring is done should be corked at once and every part of the box made practically air-tight. The smaller and tighter the compartment the less will be the quantity of anesthetic required. The box should not be opened within half an hour.

In removing a fox's pelt a slit is made in the skin with a sharp-pointed knife, beginning on the bottom of one hind foot and extending up the back of the leg to the vent and thence down the other hind leg to the foot. The entire body is removed through this opening, using the knife to separate the skin when necessary, and proceeding down over the head to the lips, where the final cuts are made. The tail bone must be carefully withdrawn, preferably by using as a vise two firmly held sticks (or a split stick), through which the bone is passed. To facilitate this it is usually desirable

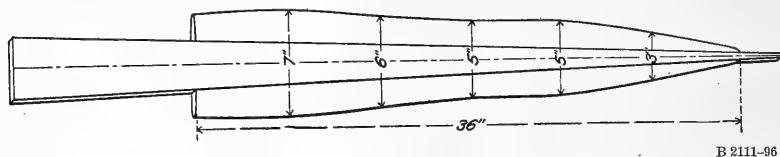


FIG. 22.—Diagram for stretching board for casing skins. The wedge makes it adjustable in width and facilitates removal from a skin.

to slit the tail on the underside. Thus the skin is turned completely inside out. It is then carefully fleshed—that is, all the fat and bits of flesh adhering to it are removed.

To dry the skin, it is first drawn, flesh side out, over a stretching board, like the one illustrated by figure 22, and hung by the nose in a cool, dry place. Within a day or two, while the legs are still pliable enough to be turned, the board is withdrawn and the pelt reversed, after which the drying is continued. Pelts should not be exposed to sunshine, as it fades them and, through its action on fat, makes them brittle.

LEGAL ASPECTS.

Popular opinion regarding the economic importance of wild foxes varies in different regions. As a rule they are unmentioned in game laws. In Rhode Island, where poultry raising is a prominent industry, foxes are considered a nuisance and a bounty of \$3 each is offered for their scalps. Connecticut has recently repealed a similar law. In certain localities in the Middle Atlantic States the animals are esteemed for the sport they afford in the chase, and on this account

are protected from trapping at all times and from any molestation during an annual close season.

In several of the States in which fox farming is or may be carried on, foxes are protected to some extent on account of their fur value. Here, unless provision is made to distinguish between wild and domestic animals, owners of fox ranches will be more or less hampered by game laws. These States are New Hampshire, Vermont, Delaware, Tennessee, Ohio, Michigan, and Missouri. Young foxes are sometimes secured by digging them out of their burrows after they are large enough to be raised. This method is more humane than using the steel trap, and, furthermore, is desirable because young animals tame more readily than adults. It can not legally be employed, however, where there is a close season for foxes unless the law provides for propagating purposes. Such a provision has been made by the Department of Commerce in its regulations to govern the taking of fur animals in Alaska, where, although foxes may not be disturbed during the breeding season, they may be taken alive for propagating purposes between July 1 and March 15 next following. Before one can engage in fur farming in Alaska a license must be secured from the Department of Commerce, Washington, D. C., and all shipments of fur out of the Territory must be reported to that department. The possession and barter of unprime skins is prohibited.

In this connection the availability of Alaskan islands for fur farming and the regulations governing their use may be considered. While many of these islands are suitable for raising blue foxes, it is doubtful if any are well adapted for silver foxes. At all events, the red fox native to the coast side of the mountains in Alaska, although large, has inferior fur. The Aleutian Islands are undoubtedly not suitable for silver fox breeding. The necessity for segregating silver foxes by fences, singly or in pairs, takes away the chief advantage which an insular location was formerly supposed to offer. The uncertainties of food and transportation are additional insular disadvantages. On the other hand, islands are usually free from outside disturbances, and for this reason, perhaps more than any other, inquiries are occasionally received as to how they may be occupied. The islands off the mainland and peninsula of Alaska, excepting those in national forests, are under the jurisdiction of the Secretary of Commerce, who, at intervals, advertises to lease to the highest responsible bidder the exclusive right to propagate foxes and other fur-bearing animals on certain specified islands. Only American citizens, or companies, or corporations organized under the laws of a State or Territory are permitted to lease or occupy them. Each lessee must make sworn annual reports, containing details of all such facts and operations as may be required, on blank forms furnished

by the Department of Commerce.¹ The Aleutian Islands and islands included in national forests are under the jurisdiction of the Secretary of Agriculture.

Game laws and regulations are notoriously subject to change. Each legislature and each new régime modifies them more or less. Those outlined above are likely to be modified or displaced altogether within a few years. Therefore, until domestic foxes attain the status of other domestic animals and are freed from the application of game laws, persons intending to breed or deal in them should first inform themselves as to the bearing of current laws upon the proposed enterprise.

SUMMARY.

The silver fox is a color phase of the common red fox. The beauty and rarity of its pelt have made it the most valuable of fur animals. It was first successfully domesticated in 1894 in the Canadian Province of Prince Edward Island. In 1910 pelts from ranch-bred foxes brought higher prices than those from wild foxes, the average value being over \$1,300 each. Since that time the demand for breeding stock has been so great that very few domesticated foxes have been slaughtered. Prices of live foxes soared beyond reach of the ordinary purse, but they have declined heavily since the beginning of the European war. Stock companies, some of them very much over-capitalized, have been organized to engage in the new industry, which thus has suddenly been transformed from a secret enterprise into a widely heralded speculation. One of the favorable results of this expansion has been a careful study of foxes in domestication, and this will contribute materially to the permanence of fox farming.

A fox ranch should be situated where it will have good drainage and be partially shaded by a young growth of deciduous trees. Each pair of foxes should have a runway of about 2,500 square feet. They thrive on a varied diet, including meat, fish, bread, mush, milk, and table scraps. The reproductive period is about 10 years. The young are born in April or May, the average litter containing four cubs; but as only about half of the captive females produce young in any given year, the annual increase has not averaged above 100 per cent.

Foxes bear captivity well. No widespread disease has appeared among them. Wounds heal readily, and cases of sickness are usually attributable to a lack of proper care. By selective breeding the originators of fox culture produced a superior strain of animals in the course of a few years. This fact is an assurance that even greater improvements can be achieved by selecting, from different geographic races, foxes of the largest size and crossing them with animals having the finest fur.

¹ Full information regarding leasing Alaskan islands may be had by addressing the Secretary of Commerce, Washington, D. C.

The exceedingly high value of silver foxes has led to the adoption of a variety of precautions against their loss. On the more pretentious ranches the animals are regularly examined by a doctor and guarded by watchmen, bulldogs, and burglar alarms. Cats are kept to act as foster mothers to orphan cubs. Foxhounds are trained to overtake and hold without injury foxes that have escaped, and bloodhounds are employed to track thieves.

The cost of yards runs from \$100 to \$150 each, and that of foxes from \$150 to \$250 for common silver foxes up to several thousand dollars for the best silvers. The price of foxes will decline as the supply increases. The profits from breeding silver foxes have thus far been very large. So long as the demand for breeding-stock exceeds the supply, the value of the annual increase, or the gross income, will average approximately 100 per cent of the value of the breeding stock. When part of the increase can be disposed of only by slaughtering for fur, profits will be less than at present, but even then they are likely to be much greater than from ordinary lines of husbandry involving like capital and attention.



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CHARLES J. BRAND, Chief

Washington, D. C.

September 15, 1915

APPLE MARKET INVESTIGATIONS, 1914-15.

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INTRODUCTION.

During the season of 1914-15 the Office of Markets and Rural Organization studied certain phases of apple marketing and distribution. This work began with an investigation of commercial apple crop conditions, and when the marketing season opened in September investigations were made in the orchard district of New York State and in the apple markets of New York City, Buffalo, Chicago, Milwaukee, Detroit, St. Paul, Kansas City, St. Louis, and Louisville.

In the height of the season an investigation of the movement of cold-storage apples was initiated, and this investigation extended throughout the entire season, with the monthly publication of information regarding the marketing of storage apples.

This bulletin, therefore, is not a comprehensive treatment of the subject of apple marketing, but rather is a report of such investigations as the Office could carry on in its present stage of development.

NOTE.—This bulletin is of general interest to apple growers, shippers, dealers, transportation companies, and consumers, and to all engaged in the trade in apples and fruits.

CONDITIONS PRECEDING THE MOVEMENT OF THE CROP.

A study of the commercial crop conditions throughout the summer of 1914 revealed the fact that the country would produce one of the largest apple crops in its history. Information in this respect was secured by the Office from special correspondents in the commercial orchard districts. Remembering that the total production far exceeds the market surplus, especial distinction was made in gathering the information. It is generally thought that the market surplus or the commercial crop ranges between 40 and 50 per cent of the total production in ordinary years. The results of investigations conducted by the Bureau of Crop Estimates indicate that 41 per cent of the 1913 apple crop and 38 per cent of the 1914 crop were "shipped out of counties where grown."¹ Formerly the estimates of the Department had been made in terms of percentages. However, in compliance with a demand for such information, the Bureau of Crop Estimates issued in terms of bushels its first quantitative report in August, 1914. The information published was secured from the Bureau's crop correspondents located throughout the United States, and related to total production only.

EFFECT OF THE WAR UPON EXPORT PROSPECTS.

With the opening of the European war it was not thought that the United Kingdom and the Continent would draw their usual supply of American apples, and a severe decrease in export demand appeared to be so imminent that the Office of Markets and Rural Organization issued a warning to growers and shippers, advising them to be exceedingly cautious about shipping apples to seaboard for export, unless steamer space and a certain demand on the other side were assured. The general trade forecasts gave the impression that the European markets were not to be counted on seriously as offering an outlet for a large amount of apples. In the past the influence of English and continental markets upon conditions at home have been strong, although the quantity of fruit shipped is not large as compared with the market surplus, and when it appeared that the European outlet would be closed a serious depression ensued.

EFFECT OF THE WAR UPON THE HOME MARKETS.

The most serious effect of the war upon the business conditions which preceded the movement of the crop and which followed throughout the marketing period was a contraction of credits in the United States and a resultant lack of confidence on the part of the trade. The South, which consumes a large quantity of apples, was especially restricted in credits, owing to the condition of the cotton

¹ Farmers' Bulletin 672, p. 6.

market. Combined with the prospects for a very large crop of apples these business conditions created directly or indirectly by the war caused a depression in opening values; but really, as may be shown later, this depression may have been very beneficial for the reason that the market opened on a low level, thereby creating an unusual consumptive demand for the fall and winter months.

The results of the investigations that preceded the movement of the crop were published in the *Agricultural Outlook* of September 16.¹ In that connection, practical suggestions were made for the proper handling of the crop, including a general forecast of market prospects.

CONDITIONS IN THE NEW YORK STATE ORCHARD DISTRICT.

One of the investigators visited the orchard district of New York State. This section had suffered from excessive rains, with the result that the Greening crop had been badly damaged by a fungus and it was feared that the Baldwin crop would suffer likewise. Speculators and operators were paying the farmers at this time for such varieties as Greening, Baldwin, Spy, etc., \$1.35 to \$1.50 per barrel f. o. b. loading station. This was for New York A grade (2½-inch minimum) fruit, packed and branded in compliance with the New York State law. The B grade (2 to 2½ inch minimum) of these same varieties were bringing \$1 to \$1.25 f. o. b. loading station. For King, farmers were receiving \$1.75 to \$2 per barrel for A grade fruit, and \$1.50 for B grade. These prices were for barreled apples f. o. b. cars or delivered to the storage houses.

The following estimates were given as the expense incurred in picking, grading, packing, and marketing a barrel of apples: The standard apple barrels cost 40 cents each; pickers received 15 cents per barrel of loose, unpressed, ungraded fruit. It cost 10 cents per barrel, piecework, for grading and packing, and 5 to 10 cents for hauling from the orchard to the loading station or storage warehouses, the total expense being 70 to 75 cents per barrel.²

As a result of the defects caused by rainy weather and also because of the grower's fear of not being able to pack according to the New York law, large quantities of fruit were being sold to buyers who shipped it in bulk to the consuming markets. Growers were being paid 50 cents per hundredweight for this fruit delivered on the car. Most of the buyers specified that the fruit be 2 inches minimum in transverse diameter. Many cars, however, contained ungraded fruit, and much worthless stock was sent to market. The marketing of fruit in this manner would have been thoroughly good business had the inferior portion been left at home. In many cases such stock

¹ Farmers' Bulletin No. 620, pp. 15-16.

² Bulletin 130, U. S. Department of Agriculture "Operating costs of a New York apple orchard," gives comprehensive information regarding the cost of preparing barreled apples for market.

had to be discarded at destination and as a result the returns from the sale of the merchantable grades were reduced materially by the cost of shipping and handling the unmerchantable fruit. It can not be said that the consumer paid more for good apples, because the wholesale buyers as a rule discount sufficiently the price paid to the farmer so that all costs and other losses for handling this character of mixed stock will be met.

The operation of the New York standard package and grade law was noted especially, and information regarding its results will be found on page 13.

STUDIES IN THE MARKETS.

TRACING DISTRIBUTION.

The mediums through which apples usually pass in the large markets are the wholesaler, jobber, and retailer. In the case of consignments, the sales are usually made by the commission merchants to the jobbers. Frequently a wholesaler, commission merchant, or jobber performs the functions of all three, so that there is no distinct line which apples may be said to take in process of city distribution.

Growers east of the Rocky Mountains form market contacts in many ways. Frequently the original sale is made at the orchard to local or itinerant buyers, who sell to large operators or city dealers. The brokers in the producing areas and in the market centers do a large business as salesmen or purchasing agents for all those engaged in the distribution to retailers. Such are the usual steps when the growers act individually. Collectively or cooperatively short cuts are possible, because through organization all the growers of a community may make direct market contacts with the city dealers.

In those markets where investigations were carried on an effort was made to trace the distribution of specific lots of apples through to the consumers in order to observe the various steps and ascertain the cost of handling, including trade margins. It proved very difficult, however, in most cases, to trace the whole of any original shipment through to its final sale to the consumer, and the larger the city the more difficult the tracing.

It is easy to trace wholesale lots from the shipper to the wholesaler, but just as soon as the lot is broken up the record of its disposition becomes more difficult to obtain. The wholesaler may sell to the jobber or to the retailer or perhaps direct to some large consumer. He will probably have a record of the sale to a jobber, but many of his sales to retailers are likely to be in small quantities, for cash, and without record of the purchaser. The jobber, in turn, may sell either to a retailer or to a large consumer, and a very large part of his sales are likely to be for cash, without further record. It is possible, therefore, to follow only a small part of the shipment even so far

as the retail dealers. Further, a considerable part of the retail business is handled by hucksters, from whom it is difficult to get much satisfactory information with regard to sales and expenses, even if it were possible to find out from the wholesaler or the jobber what particular hucksters had purchased the apples that were being traced. And, in addition to the lack of records on the part of the dealers, the problem is often complicated by the fact that in some cities half a dozen nationalities may be represented in those receiving parts of a single original shipment. This is especially true in New York City.

RETAIL METHODS AND COSTS.

In studying the various phases of city apple marketing, special attention was given to retail methods and costs. The purpose of this study was chiefly to learn whether the wholesale supply controls the price. The cost of operation as a factor in determining retail prices also was investigated as far as possible.

Retail apple distributors may be classed as follows:

(a) Fruit-stand vendors.

(b) Fancy grocers, fruiterers, etc., catering almost exclusively to high-class or fashionable trade and doing a very extensive credit business.

(c) Grocers catering to a cheaper class of trade, largely upon a cash basis.

(d) Hucksters or street peddlers.

Relatively high prices were charged for apples purchased at fruit stands. Extra fancy Northwestern and Colorado Jonathans were sold to the dealers during October and November at prices ranging from \$1 to \$1.25 per box. Apples which grade 150 to the box retailed at 2 for 5 cents, or \$3.75 per box. This meant a gross profit of about 250 per cent. In the 96 size, extra fancy Jonathans sold at 3 for 10 cents, or \$3.20 per box, showing a gross profit of about 200 per cent.

In the East Side tenement section of New York City it was learned that by reason of the cheap prices prevailing and the heavy supply of apples arriving the peddlers were operating to the detriment of fruit stands. The fruit-stand dealers were selling only about one-third to one-half the quantity of fruit handled in former seasons. The pushcart and wagon peddlers as a rule buy packed or loose fruit cheap and go direct to the homes of the residents, selling at prices considerably below the fruit-stand men. The peddlers handle a large quantity; make quick cash sales, and pay no rents. Other dealers incur heavy operating expenses and generally sell not for the purpose of moving a large quantity, but for the highest price obtainable. Consequently, the movement is restricted.

The largest profits were found usually in barreled apples. For instance, New York B grade, 2 inches minimum, approximately 600 apples to the barrel, sold for a cent each or \$6 per barrel. These apples cost the retail dealer not over \$2 per barrel delivered to his store, allowance being made for jobber's profit and drayage. The investigator saw "A grade" fruit, 2½ inches minimum, averaging about 400 apples per barrel, which cost the retailer not over \$3, being displayed for sale at 2 for 5 cents, or \$11.25 per barrel. Such prices prevailed at no less than 25 retail stores visited in one day. Apples were being offered for sale at retail all over New York City at prices ranging from 1 cent each at the cheap corner fruit stands, to 50 cents and 80 cents per dozen at the fanciest fruit stores.

In general, it may be said that the gross profits of fruit-stand vendors range from 100 to 250 per cent. Operating expenses other than rent in most cities except New York are not relatively high and all sales are on a strictly cash basis; hence the net profits on good fruit are large.

Grocers catering to high-class trade buy only the best apples. Extra fancy Jonathans, Grimes, etc., preferably 138's and 150's size, were purchased at \$1 to \$1.25 per box. These apples were taken from the box and repacked in small splint trays similar to the peach basket used in a six-basket carrier. Each box of apples filled approximately 10 trays. Each tray sold for 30 cents; hence the box brought \$3, representing a gross profit of about \$1.75. Extra fancy Delicious and Winter Banana, 72's size, purchased at \$2 per box, retailed at 5 cents each, or \$3.60 per box. Other sizes and varieties brought corresponding prices. No attempt was made by this class of grocers to stimulate consumption by temporarily reducing prices.

The retail prices quoted above were maintained consistently throughout the 1914 season, regardless of prevailing jobbing prices. The large margins charged by the retailers, for the most part, were due apparently to the small amount of business handled, the perishable nature of the commodity, and the cost of operation.

An elaborate and efficient delivery service must be maintained by the grocers, and many small deliveries are made each day at an actual loss to the dealer. A large proportion of the grocery-store patrons buy on credit and pay when it becomes convenient. Many of these accounts are never paid. Hence it becomes apparent that the good customer who pays his bill regularly each week, or who pays cash, must suffer for the shortcomings of others. However, there can be little doubt that reducing prices would materially increase consumption and in the end result in equally good profits for the retailer. Reduced prices and better business practice should prove to be very beneficial to grower, dealer, and consumer.

The profits derived from the sale of cheaper grades of apples to the poorer class of consumers are not so large. It was learned that those catering to such trade operated on a margin of 75 to 100 per cent of the purchase price. Table 1 shows the purchase and selling prices of certain varieties of apples handled by retail grocers in St. Louis, Mo., on October 13 and 14, 1914.

TABLE 1.—Purchase and selling prices of apples handled by retail grocers in St. Louis, October 13 and 14, 1914.

Variety.	Purchase price per barrel.	Selling price, per peck, ¹ received by 10 retail grocers.									
		No. 1.	No. 2.	No. 3.	No. 4.	No. 5.	No. 6.	No. 7.	No. 8.	No. 9.	No. 10.
		<i>Cts.</i>	<i>Cts.</i>	<i>Cts.</i>	<i>Cts.</i>	<i>Cts.</i>	<i>Cts.</i>	<i>Cts.</i>	<i>Cts.</i>	<i>Cts.</i>	<i>Cts.</i>
Ben Davis.....	\$1.55 to \$1.75..	25	25	25	25	25	25	30	30	30	30
York Imperial.....	2.25 to 3.00..	35	35	35	35	35	35	40	40	40	40
Jonathan.....	² 1.00 to 1.25..	40	40	40	40	40	40	40	40	40	40
Spy.....	2.75 to 3.00..	40	40	40	40	40	40	40	40	40	40
Gano.....	1.65 to 1.80..	25	25	25	25	25	25	25	25	25	25
Rome Beauty.....	1.65 to 2.60..	30	30	30	30	30	30	30	30	30	30
Hubbertson.....	1.75 to 2.50..	35	35	35	35	35	35	35	35	35	35
Missouri Pippin.....	1.30 to 1.65..	15	15	15	15	15	15	15	15	15	15
Greening.....	2.00 to 2.15..	25-0	25-0	25-0	25-0	25-0	25-0	25-0	25-0	25-0	25-0

¹ Grocers secure 12 to 13 pecks from a barrel of apples; 4 pecks from a box of apples.

² Per box.

By keeping prices at a rather high level, the stores move only a small quantity each day. Considering the fact that overhead and operating charges are not so high as in the case given above, and that there is a greater proportion of strictly cash trade, it appears that the margin of profit is rather great. It is reasonable to believe that sales could be made on a very much closer margin and still offer ample protection and profit to the dealer. These grocers, however, seem to prefer handling small quantities rather than moving large quantities upon small margins.

The peddler and pushcart men truly may be called distributors. These dealers are large factors in creating a demand for fruit. They make an effort to find customers and by so doing dispose of a large quantity. As a rule, they handle only the poorer grades, buying extra fancy and fancy boxed apples only when the price is extremely low. This year they handled more box apples than ever before, and the margins were small. The circumstances under which they work enable them to make a close price, and it seems certain that any reduction they could afford to make would not affect materially the rate of consumption. In general, it appeared that retail apple prices were too high this year, and there is little doubt that the amount used would be increased greatly if grocers would buy in larger quantities and sell at a price sufficiently low to attract public attention.

In a middle western market there is a chain of retail stores which handle apples in a very original manner. They sell for cash, make no

deliveries, and have no telephones in their stores. Their plan is to sell a peck of apples proportionately as cheap as they could sell a barrel. The concern publishes a weekly newspaper which in one week had a circulation of 26,000 copies. In this paper they advertised the commodities on which they would make special prices. On November 4, 1914, they quoted "Excellent cooking apples," which cost them about 10 cents, at 15 cents per peck. This company moved a large quantity of fruit through their various stores at low prices, made a profit of about 50 to 60 cents a barrel, and enabled the consumer to buy far below the usual retail prices.

The investigator also secured the record of sale of 118 barrels of apples through 5 and 10 cent stores. The complete distribution of this lot from grower to consumer is given in Table 2.

It will be noted that the 5 and 10 cent stores handled this fruit for 21.8 per cent of the consumer's dollar. A large Pacific coast growers' organization, in its efforts to secure a record of the distribution of the orange consumer's dollar, secured reports covering the market prices of oranges for a whole year. When these reports were tabulated it was found that 33½ per cent of the orange consumer's dollar remained with the retailer. So it would appear that through distribution conducted as in the case given above a saving of 11.53 per cent can be effected, it being granted that apples and oranges are retailed in a similar way.

TABLE 2.—*Distribution of the consumer's dollar in a sale of 118 barrels of apples distributed through medium of 5 and 10 cent stores.*

	Retail costs per barrel.	Per cent of consumer's dollar.
Grower received (on the tree).....	\$1.455	38.49
Cost of barrel, picking, grading, packing, and hauling.....	.66	17.46
Fruit growers' association selling charges.....	.135	3.57
Freight, origin to destination.....	.416	11.00
Cartage at destination (depot to store).....	.05	1.31
Loss (shrinkage) to wholesaler.....	.032	.84
Cost to wholesaler.....	2.748	-----
Wholesaler's profit.....	.208	5.53
Cost to 5 and 10 cent stores.....	2.956	-----
Profit to 5 and 10 cent stores.....	.824	21.80
Price paid by consumer.....	3.78	100.00

For distribution and costs this lot of fruit was marketed very satisfactorily, but of course the case is not typical of retail handling. It is interesting to note that the distribution was from a growers' association through wholesaler and retailer to consumer. In the large cities the jobber usually intervenes between the wholesaler and retailer, while wasteful methods and costly service come between the retailer and consumer, with the result that prices are charged which may be prohibitive of heavy consumption.

MARKET PREFERENCES FOR VARIETIES.

It can be truly said that most markets can always find use for a good quality apple, no matter what its shape or the color of its skin may be. It is probably unreasonable to say that one market will take only certain varieties while another will take other varieties. Conditions are always changing preferences. For instance, due to low prices, there was a noticeably increased demand in some cities, known as barreled-apple markets, for box-packed fruit. The certainty of securing uniformly sized, highly finished fruit at extremely low prices was the only reason given for this condition.

To illustrate how a market takes a new apple, it may be stated that on October 27 two cars of extra fancy northwestern boxed fruit of little-known variety sold to the retail trade at 75 to 85 cents in one of the markets. Three days later apples of the same grade, pack, and variety were selling well at \$1.25 because they had become better known. It must be said, however, that markets do not usually exhibit such quick action in taking up new varieties of fruit. A new variety must have exceptional merit to cause a market to act as quickly as in the above case.

GRADES—BOXED, BARRELED, BULK.

As has been mentioned previously in this publication under "Market preferences," some cities are known as boxed-apple markets and some as barreled-apple markets. Other cities or sections are known as good markets in which to dispose of bulk apples.

Every community, be it known as a boxed, barreled, or bulk apple market, has different classes of consumers who demand different classes of fruit. In New York City, for instance, there were received from various apple-producing sections from October 19 to November 21, 1914, 1,882 carloads of barreled apples, 383 carloads of boxed apples, and 443 carloads of bulk apples, or a total of 2,708 carloads of apples for a period of 28 business days. It can not be stated, however, that this proportion would apply in New York City throughout similar apple seasons.

Table 3 gives the number of carloads of barreled, boxed, and bulk apples received in New York, Chicago, Detroit, and St. Paul for the periods shown, and also the percentages of each class of fruit used by each market. It shows, in addition, the totals for all four markets, and the average percentage of barreled, boxed, and bulk fruit handled jointly by all four markets. Thus it will be noted that the barrel-packed fruit predominates by over 50 per cent.

TABLE 3.—*Number of carloads of barreled, boxed, and bulk apples received in cities named.*

City.	From—	To—	Number of business days.	Carlot receipts.						Total.	
				Barreled apples.		Boxed apples.		Bulk apples.			
				Cars.	Per cent.	Cars.	Per cent.	Cars.	Per cent.	Cars.	Per cent.
New York.....	Oct. 19	Nov. 21	28	1,882	69.5	383	14.15	443	16.35	2,708	100
Chicago.....	Sept. 15	Dec. 5	70	1,683	41.96	900	22.44	1,428	35.60	4,011	100
Detroit.....	Nov. 2	Nov. 30	24	140	53.23	8	3.04	115	43.73	263	100
St. Paul.....	Oct. 16	Nov. 17	27	318	60.46	99	18.82	109	20.72	526	100
Totals and averages.....				4,023	53.58	1,390	18.52	2,095	27.90	7,508	100

Detroit was receiving such heavy supplies of bulk fruit from the Michigan orchards, and it was selling so cheaply, that western and northwestern growers were practically unable to make any sales in that market. It will be noted that 8 cars of box-packed apples were all that Detroit handled. New York received an average of 96 carloads of all classes per day. It must be remembered, however, that New York is a large export market. All of these apples came direct to the New York terminals, part going into immediate consumption, part into cold storage, and part being exported. In most cases the fruit exported from the port of New York, however, was billed direct, origin to destination via New York City, and these cars were not recorded as having been received by the local freight offices.

It was interesting to note that the boxed fruit this season went to all classes in New York City, rich and poor alike, while in normal seasons only the rich and moderately well-to-do middle classes could afford to purchase such fruit. This condition existed also in other markets, and the extremely low price at which boxed fruit sold this year was the cause of this condition. Well-graded and highly-colored barreled fruit also reached this same class of trade. Low grades of barreled fruit and all bulk apples went to the pie men and the poorest people.

Knowledge of the requirements, customs, and changing conditions of the markets is most important in selling apples. The growers can acquire this knowledge best through efficient cooperative organizations, with capable sales managers in charge.

THE EFFECT OF INFERIOR APPLES UPON THE MARKET.

An effort was made in some of the markets visited to study the movement of low-grade apples and the general effect of such movement on the apple market in general. Judging from observations

made from September 15 to December 5, inclusive, and the statements of large apple dealers, the investigator in the Chicago market found that approximately 25 per cent of car-lot bulk arrivals, equivalent to about 350 carloads, and 10 per cent of the contents in barreled shipments, equivalent to about 160 carloads, or a total of about 510 carloads of the apples received, were so poor in grade and quality that they would not have brought freight charges had this kind of fruit been received in straight carload quantities.

Those farmers shipping apples to Chicago that season would have saved the cost of their barrels and the packing, loading, and part of freight charges had they eliminated the poor fruit. They also would have relieved their market, thereby giving the good stocks an opportunity to net a reasonable and profitable return.

Similar conditions were found to obtain in Louisville, Ky., where a large portion of the bulk apples received were bruised and covered with mud or otherwise soiled, showing that the fruit either had been blown off the trees or else had been shaken off by the grower. Such apples also showed decay.

In one instance the commission merchant to whom was shipped a car of inferior York Imperial apples, which arrived at Louisville about November 16, 1914, wired the shipper that he could not handle them advantageously, and the consignment was delivered to another dealer. The apples were sold "for grower's account" at 40 cents per 100 pounds. The railroad waybill indicated a total weight of 19,000 pounds, and the statement of sales is as follows:

Gross sales, 19,000 pounds, at 40 cents per hundredweight.....	\$76.00
Freight.....	\$52.00
Commission for selling, at 10 per cent.....	7.60
Total charges.....	59.60
Net proceeds.....	16.40

It is seen that this sale netted the grower just \$0.0863 per hundred-weight, an amount which barely paid the cost of assembling the fruit for shipment. Moreover, the purchaser of the car lost about 25 barrels on account of decay.

Plate I shows the contents of one barrel of apples inspected and regraded by the investigator in New York. The fruit was supposed to be strictly No. 1 grade, 2½ inches minimum in transverse diameter. The larger pile, representing about two-thirds of the barrel, were true to grade. The smaller pile contained culls. The investigator had no trouble in finding this barrel of apples, and could have found others just as poorly graded. The condition of the original pack indicated ignorance, carelessness, or "sharp practice" on the part of the packer.

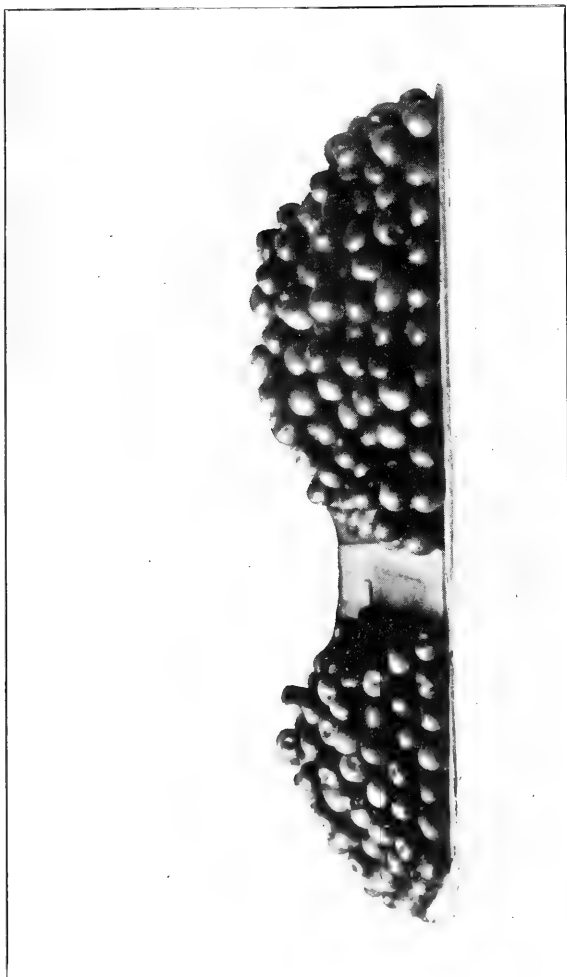
SHIPMENTS UNDER VENTILATION AND REFRIGERATION.

Some cars of apples inspected in the markets visited showed softness and decay. It was thought this was due to lack of refrigeration, poor ventilation, or poor grading of the fruit itself before being packed and loaded on the cars.

Of the three classes of fruit (boxed, barreled, and bulk) consigned to the markets, the box-packed apples usually arrive in the best condition. This class of fruit is usually well graded and tightly packed, thus giving assurance of its carrying well. The principal fault found with box-packed apples (especially the Jonathan variety) during the 1914-15 season was that a large percentage of the shipments arrived in overripe condition. At first it was thought that this may have been due to shipping this variety without refrigeration during the warm weather of the early fall months in order to save refrigeration costs. It was learned, however, that weather conditions and failure of the grower to gather the fruit at the proper time caused the Jonathan's to be overripe at time of shipping. While refrigeration may have retarded the deterioration, still it was a question if the extra cost would have been justified, so in most cases such fruit was rushed in ventilators to the nearest markets. Under the conditions no power could have delivered this fruit in good condition and the results secured were only to be expected.

Coming to markets already heavily supplied with first-class fruit and of necessity being destined for prompt consumption on account of their condition, these apples sold for prices slightly below the market for stock with keeping qualities. Dealers who ordinarily would have paid fair prices feared to do so in direct competition with good, firm stock. On the Kansas City market alone it was learned that approximately 20 cars of boxed apples from the Northwest were sacrificed on account of arriving in ripe condition. It is thought that these apples sold at a discount of approximately 25 cents per box, for, although they were in fair condition for immediate consumption, they had no storage value.

It is desirable for the growers to realize that no expenditure for refrigeration or cold storage can compensate for failure to pick and pack at the proper time. The refrigeration of overripe apples will not restore them to a sound condition nor prevent their progressive deterioration either in transit, in storage, or in the market. On the whole, there was noticeable a great improvement in all barreled stock arriving. The regulatory law of New York State caused the growers and packers to grade more closely and to display their names on the heads of the barrels. Thus poor, wormy, fungous, or scabby fruit, that formerly went to market in barrels, generally was kept at home.



A BARREL OF APPLES REGRADED IN NEW YORK BY INVESTIGATOR—ONE-THIRD CULLS.

Great improvement could have been made in shipping bulk fruit. A number of cars arrived in bad condition, due principally to two causes. First, large quantities of undersized, wormy, bruised, and otherwise defective fruit were shipped in heavily loaded cars and decayed easily when subjected to the heat generated in fresh vegetable products placed in bulk. Furthermore, bulk fruit was shipped frequently in ordinary box cars. It was impossible properly to ventilate the fruit in these cars, although attempts were made in some cases to slat the doorways, thus allowing a slight circulation of air. Some shippers used foresight and good judgment in ordering ventilators far in advance of shipment, but it is impossible to secure this equipment at all times when the movement of fruit products is heavy.

Many consignments of properly picked and graded bulk fruit arrived in very poor condition, because they were loaded in improperly constructed cars. Other consignments of bulk fruit, having been shipped under proper conditions, arrived at the markets in such good shape that the owners packed the fruit in barrels and placed it in cold storage.

In some cities the transportation companies provided for the fruit a minimum of protection from the weather. After a few days of continuous rain in St. Louis, Mo., the investigator of this office visited the levee, where thousands of barrels had been stacked three tiers high. It was noted that the commission men had attempted to protect the barrels with tarpaulins, but this was insufficient. The coverings failed to cover all of the barrels, and those at the bottom of the stacks were thoroughly soaked also as the water ran down the levee. These barrels immediately swelled, the hoops split, and the heads and staves bulged. The fruit depreciated 25 cents or more per barrel on account of poor terminal facilities.

GRADE AND PACKAGE LAWS.

In New York State the effect of the apple grade and package law was studied. The law is mandatory and provides for four grades—"Fancy," "A grade," "B grade," and "Unclassified." Very few growers packed the "Fancy grade," because they thought its specifications too strict, and owing to the large crop and scarcity of labor there was a tendency to pack those grades which could be prepared most easily.

The first year's operation of this statute resulted in a marked improvement in the marketing of the apple crop of the State, and it is generally conceded that it has been very beneficial. It established confidence at a time when confidence was sorely needed. Its grades for the most part proved to be a common language between the

shippers and receivers, sales being made readily and adjustments of difficulties more easily effected upon the basis of its standards. It may be said that the New York growers strived to comply with the law. Many, fearing that they could not do so, marketed their crops in bulk during the fall, and much inferior stock was kept at home, thus leaving the market to the better grades.

The New York State law differs from the Federal apple grade and package law, commonly known as the Sulzer law, which is not mandatory. Some packers who may have failed to comply with or who did not desire to grade by the New York State law have attempted to take advantage of the conflict between the two laws. The New York State law does not prevent compliance with the Sulzer but imposes additional requirements as to grading. It frequently occurred in case of condemnation by the State inspectors that the packers erased the New York markings and substituted brands allowed by the Federal law.

With the enactment of grade and package laws in other Commonwealths, there are likely to be many conflicts between the laws of the States and between State and National laws. The advisability of uniformity in legislation along these lines is apparent. Maine and Vermont now have individual laws providing for standard grades and packages for apples, and legislation is pending at present in Massachusetts, New Hampshire, and Connecticut. These laws are all very similar, and it is believed the fruit interests of the various sections will cooperate in securing as great uniformity as possible. Utah, Oregon, Washington, Montana, and Idaho have laws fixing the standard box and providing for the elimination of wormy fruit, but the grades are not specified. These laws are believed to have rendered an excellent service in improving the general quality of fruit grown in the sections affected.

COLD-STORAGE HOLDINGS AND MOVEMENT.

Reports emanating from unofficial sources indicated that sufficient cold-storage space was not available in the fall of 1914 for conserving the supply of apples for distribution throughout the winter and spring, and it is claimed that large quantities of apples wasted in the orchards for lack of storage facilities.

Cold-storage owners must fill their space for as much of the year as possible. Eggs, butter, and other commodities are sources of revenue during the summer and early fall, especially in the markets, but these commodities generally give place sufficiently by the first of October to provide for the apple crop. During the past season, however, the egg market was very inactive, and stocks cleared very slowly. Space for apples, therefore, was in great demand, and many storages would quote only a season rate, whether the fruit was to be stored for a long

or short term. There is no indication that the rates were increased; on the other hand, in western New York the storage firms reduced the usual 50-cent charge to 40 cents on account of the low prices which were being paid for apples.

Until the past season accurate information regarding the quantity of apples placed in cold storage and the progress of the movement during the winter and spring has not been available to the public. In October the Office of Markets and Rural Organization undertook to secure and publish the data, so that growers and dealers alike might direct the sale of their holdings in an intelligent manner.

The cooperation of the cold storages was solicited for this purpose, and a large number assisted in making the office reports valuable. However, many concerns failed to answer the inquiries which were sent to them at the end of each month, and many submitted only partial reports, some reporting one month and failing to do so the next. The holdings of such firms necessarily were eliminated from consideration in estimating the progress of the movement, for the reason that a comparison between the holdings from month to month with the holdings on December 1 is necessary for determining the movement.

The office mailing list now includes the names of 667 cold-storage firms. Of these, 443, with a capacity of 8,902,013 barrels, have reported their holdings one or more times during the season. The balance, or 224 concerns, failed to reply at all. It was not possible, therefore, to publish quantitative reports showing the total number of barrels and boxes held. Still, the number of firms which responded was thought to be sufficiently large to justify the issuance of percentage reports through the medium of the press. This was done monthly, and a detailed report of each investigation was printed in the current number of the Agricultural Outlook and mailed to the cold storages, trade papers, and individual growers and dealers. These investigations embraced the holdings of apples not only during the season of 1914-15, but also of 1912-13. The crops of the two years were similar, and it was thought that a comparison of the holdings would be helpful to growers and dealers in arriving at true values.

Estimating upon the basis of the reports received, it was found that the holdings on December 1, 1914, amounted approximately to 11½ per cent more than those of December 1, 1912; on January 1, 1915, 23 per cent more than January 1, 1913; on February 1, 1915, 28.4 per cent more than February 1, 1913; on March 1, 1915, 5.7 per cent less than March 1, 1913; on April 1, 1915, 15.6 per cent less than April 1, 1913; on May 1, 1915, 13.2 per cent less than May 1, 1913.

Of the total number of storages reporting, it was found that 289 responded December 1; 306, January 1; 280, February 1; 289, March 1; 270, April 1; and 258 on May 1. While the minimum number of

storages reporting for any one month was 258, still only 179 firms reported uniformly for each month. Estimates for the monthly movement for the entire season, therefore, are based upon this number. Table 4 shows the monthly movement from these 179 plants in terms of percentages:

TABLE 4.—*Monthly movement of apples from 179 cold storages reporting—estimated on the basis of their total holdings December 1, 1914.*

Month.	Per cent of barrels.	Per cent of boxes.	Per cent of total holdings.
December.....	11.1	5.7	9.7
January.....	20.1	12.3	18.1
February.....	20.5	26.2	21.9
March.....	24.5	26.3	25.0
April.....	14.5	15.6	14.8

There remained in storage on May 1 approximately 10 per cent of all apples held in the coolers on December 1, if the conditions existing in these plants may be accepted as a criterion of the general situation. It is interesting to note that the market supply of apples as indicated by the 179 plants on May 1 was 13.2 per cent less than May 1, 1913, whereas the crop of last year was much in excess of two years ago.

It would appear, then, despite the war and depressed conditions here, that the actual movement of apples from cold storage has been very satisfactory in comparison with 1912-13. It is thought that the liberal consumption of this fruit was due to the uniformly low prices which prevailed in the early fall and throughout the entire year. In February, however, the situation looked especially grave, for the reports of February 1 indicated unusually large holdings. In publishing the data secured at that time the office issued a timely warning¹ to growers and dealers advising them that a regular, vigorous movement would be required to prevent disaster in the spring. Fortunately for trade in apples, the late spring prevented heavy shipments of first southern vegetables and made conditions excellent for the handling of apples, so that holdings rapidly diminished.

PACIFIC NORTHWEST APPLES VIA THE PANAMA CANAL.

Reports of four shipments of boxed apples made during the past season from the Pacific Northwest via the Panama Canal to New York City for export were secured. These shipments, which were made in December, January, and February, consisted of 54 cars and represented practically the entire quantity forwarded through the canal. With the exception of 8 carlots, all of this fruit arrived in New York in first-class condition. These 8 carlots, which represented the total

¹ Farmers' Bulletin 651, p. 10.

shipment upon one of the steamers, showed overripe condition and slight decay, supposedly as the result of poor refrigeration conditions.

All of these Panama shipments were sent across the Atlantic. Although no cold-storage space was available on board the trans-Atlantic lines, practically all of the fruit, with the exception of 8 carlots previously mentioned, was said to have shown excellent condition and sold for relatively good prices in the European markets.

The water freight rate from the Northwest ports via the Panama route to Brooklyn is 55 cents per hundred pounds, whereas the railroad rate is \$1 per hundred pounds. It is to be remembered, however, that the Panama route is available only to those fruit districts which are near the Pacific coast, and that when wharfage, dockage, and inland freight are included there is a relatively small saving even for those districts.

It is estimated that the saving to Hood River on shipments via Panama is 16 cents per box for apples which would have gone in railway ventilators and 27 cents per box for refrigerators. The saving to Yakima and Wenatchee is from 8 to 10 cents on ventilator stock and 18 to 20 cents on refrigerator stock. Owing to the long time (approximately 37 days) required for shipment through the canal as compared with shipment by rail and the resultant risks, it is thought that the actual saving per box is inconsiderable, and that for this route to be largely profitable to Pacific Northwest shippers the rate of transportation must be lowered and trans-Atlantic cold-storage space must be available upon arrival at New York City.

As far as physical handling is concerned, it is believed that the canal route has been proven entirely practicable, although its use upon the basis of present rates necessarily must be confined to shipping points near the Pacific coast and to markets on the Atlantic seaboard or beyond. Apples coming through the canal at present can not be distributed profitably inland from the Atlantic coast, for when terminal and inland charges are added this route can not compete with the transcontinental railways.

EXPORT MARKETS.

THE UNITED KINGDOM AND EUROPE.

It has been stated that prior to the shipping season of 1914 it was generally believed, under the war conditions, that Europe could not be expected to demand its usual quota of apples; consequently there was much speculation as to what would be done with the export surplus. When the crop of winter varieties began to move, shippers cautiously forwarded considerable quantities to England. Although sales were not high, the low level of prices obtaining in the United States justified continued shipments across the Atlantic.

The cheapness of the fruit invited heavy consumption, with the result that the movement increased rapidly until the quantities forwarded not only exceeded all expectations, but proved to be little short of the largest export years. The United States was favored for the reason that steamers plying between Canadian and English ports were requisitioned for transport purposes, thus placing limitations upon the exportation of apples from the Dominion.

Direct dealing with Hamburg, Germany, had increased rapidly in recent years, but this outlet into the German Empire was closed so effectually that not a single package of American apples has been forwarded direct to that port. On the other hand, the Scandinavian markets, which formerly received their supplies through English and German channels, have taken large quantities direct. This should prove to be of real benefit in future years, for the reason that when direct dealing is once established it is likely to continue.

The following statement of total export shipments from the United States and Canada during the past five years is given for purposes of comparison:

TABLE 5.—*Total export shipment of apples from United States and Canada.*

Fiscal year.	From the United States for fiscal years ending June 30.	From Canada for fiscal years ending Mar. 31.	Total.
	<i>Barrels.</i>	<i>Barrels.</i>	<i>Barrels.</i>
1910-11.....	1,721,106	523,658	2,244,764
1911-12.....	1,456,381	1,664,165	3,120,546
1912-13.....	2,150,132	1,324,769	3,474,901
1913-14.....	1,506,569	947,382	2,453,951
1914-15.....	1,846,224	1,117,336	2,963,560

¹ Official report not yet available. Number given is reported by New York forwarding agents as representing shipments from New York, Boston, and Portland.

SOUTH AMERICA.

American shippers have made a special effort to develop markets for apples south of the Equator. Direct trade with South America may be said to have begun five years ago. Prior to that time supplies had been secured principally from England and Australia, apples from the United States frequently going to these markets through the hands of English dealers. Direct sales to South American markets were small in the first year, and they were made subject to acceptance upon arrival, the shipper paying all freight and insurance charges and collecting through the medium of English banks by sight draft attached to the documents.

The shipments from New York direct to South America increased approximately 400 per cent in the first four years after direct trade began. No consignments were attempted without previous sale

until the fall of 1913, when an exporter shipped 13,000 boxes to Buenos Aires via New York and, a little later, 9,000 boxes via the Straits of Magellan.

An early opportunity was secured to dispose of the 22,000 boxes at a profit of about 40 cents a box, but a large proportion of the consignment was held too long, resulting in a loss to the shipper on the transaction as a whole. The same shipper, however, is now preparing for further shipments to South America early in the coming season, for the handling of which arrangements have already been made.

During the past year a New York firm of distributors sent a representative to study the South American markets and make trade connections for direct handling. This firm formerly had sold apples and other products to New York exporters.

The representative spent two months in South America, but met with considerable difficulty in interesting the importers, who, it appeared, were very well pleased with their trade connections in the United States. Contracts for the sale of approximately 9,000 boxes for fall delivery were secured eventually, and agents appointed in Buenos Aires. Sales were arranged upon easy terms, but when deliveries were made only 1,600 boxes were accepted, the balance of the shipment being sold by the commission agent. Thereafter regular consignments to this market were made for the purpose of supplying the demand independently of the importers who formerly had controlled the handling of this commodity. Much of the fruit has been sold at auction, circulars being previously distributed among small dealers, hotels, restaurants, etc. On March 3, 1915, 5,000 boxes of apples were sold in this manner.

It is not known just what the future results of these experiments may be. It is thought by those who have had the longest experience with South American importers that these markets can be developed best by handling the business in a manner most acceptable to the dealers. Attention is called to the fact that the importers have been accustomed to supply their markets by placing orders judiciously and receiving only such stock as has been bought previously. The consignment of apples, therefore, is severely discouraged by them, and it would appear from the experience of the past two years that those shippers who have endeavored to secure this trade by overstepping Latin customs have not been entirely successful in their ventures.

It is understood that formerly the margins of gross profits have been very large. Owing to the risks involved, it is only to be expected that this business could not be handled upon margins that might prevail in the United States or between the United States and

Europe. Apparently, American trade with markets below the Equator has been conducted with profit both to the American shipper and the South American importer. The consignment methods would seem to decrease the profits per package, and it is possible that this accounts for some of the opposition reported to have been encountered. It is too early to arrive at definite conclusions regarding the effect of these consignments upon future business.

At Buenos Aires, the chief market for this commodity, the cold-storage facilities are considered to be excellent and space for short-time storage costs from 1 to 1½ cents per box per day. Consignments to Brazil have not been attempted. A duty of \$1 per box is imposed by the Brazilian Government, and this adds to the risk of shipping fruits unsold. The chief market is Rio Janeiro, but the trade of that city is considered to be somewhat controlled by one concern, which operates the only cold-storage plant. It has been reported that a Brazilian railway company with terminals at Rio Janeiro plans the erection of a competing storage. If this plan is executed it is thought the conditions in this market would be considerably improved for receiving and handling consignments of American apples.

The ocean freight and insurance amounts to \$1.20 per box. The facilities for safe transportation have been greatly improved within the past two years, owing to an increase in the importation of fresh meat from Argentina. Refrigeration is necessary for meat transportation, and the cold chambers are well suited to the transportation of apples on the return journey. If trade in meat products between South America and the United States continues to increase, the facilities for handling large quantities of apples are expected so to improve that space will be sufficiently available to justify lower rates. When the cost of transportation and the usual trade margins are combined, it will be seen that the selling price of apples in South America of necessity must prohibit heavy consumption. If transportation facilities can be improved so as to decrease the rates and the risk of deterioration in transit, it is believed that trade margins may be decreased reasonably and that the result in price to the consumer will be such as to encourage a large increase in shipments.

In order to assure the safe transportation of apples to South America it is necessary that the fruit be carefully selected, graded, and packed by hand, special care being exercised to eliminate everything that can not be classed as "Fancy" or "Extra fancy." The box package is preferred for the reason that the fruit arrives in much better condition than when packed in barrels. To illustrate the need of care in this respect, the experience of an eastern fruit growers' association may be given. Through its foreign agent the sale of several carloads was made to a South American importer at 12

shillings per barrel delivered on board the steamer at New York City. Delivery was made and the money collected, but the future patronage of the buyer and probably the prospect of future sales in his market apparently have been lost, because the fruit was not properly graded and packed at the time it was shipped from the producing area. An investigation has shown that this fruit had been packed without inspection on the part of the organization and that the packing was done some days in advance of shipment. Only a few barrels in each lot were inspected when the fruit was loaded on the cars.

Table 6 shows the direct shipments of apples in terms of barrels from New York to the respective South American markets within the past five calendar years. The values given were those entered upon the steamship manifests and were estimated either upon the basis of the New York market or upon the value at destination.

TABLE 6.—*Exports of apples from New York to South America, by countries, during the years 1910, 1911, 1912, 1913, and 1914.*

Country.	1910		1911		1912		1913		1914	
	Barrels.	Price.	Barrels.	Price.	Barrels.	Price.	Barrels.	Price.	Barrels.	Price.
Argentina.....	1,182	\$4,340	8,464	\$36,882	6,939	\$37,511	36,513	\$158,378	28,045	\$194,358
Brazil.....	9,186	34,525	16,150	67,370	14,977	63,688	21,936	111,780	13,264	96,523
Chile.....			5	20						
Colombia.....	450	2,077	638	2,564	896	2,985	929	3,379	778	2,475
British Guiana.....	126	561	581	2,081	551	2,118	448	1,934	127	396
Dutch Guiana.....	260	1,138	273	1,137	203	750	187	763	104	327
French Guiana.....	3	12	7	26	9	33				
Uruguay.....	305	1,270	583	2,795	290	902	603	2,352	2,240	9,931
Venezuela.....	1,144	4,121	1,570	6,557	2,213	7,977	1,579	5,746	1,686	5,175
Total.....	12,656	48,044	28,271	119,432	26,068	115,964	62,195	284,332	46,244	309,185

CONCLUSION.

The information secured from the apple market investigations conducted by the office in 1914-15 would seem to warrant the following conclusions:

(1) That relatively low prices in large crop years in the beginning of the season make for quick movement and rapid consumption, with the natural result of better season averages.

(2) That the marketing of inferior grades along with good fruit in large crop years is not profitable.

(3) That the effective operation of grade and package laws may be counted upon to aid in stabilizing apple markets.

(4) That the general dissemination of accurate information regarding the holdings of apples in cold storage at stated periods tends to eliminate speculation by bringing about a more even distribution upon the basis of actual values.

(5) That the Panama Canal route may be an increasingly important factor in the distribution of apples grown along the Pacific seaboard.

(6) That the exports of apples during the season 1914-15 were large, despite the unsettled conditions caused by the war in Europe, and that a demand for American apples may be expected to continue.

(7) That apples from the United States are growing in favor with South America, and that by judicious cooperation with the Latin-American trade shipments may increase.

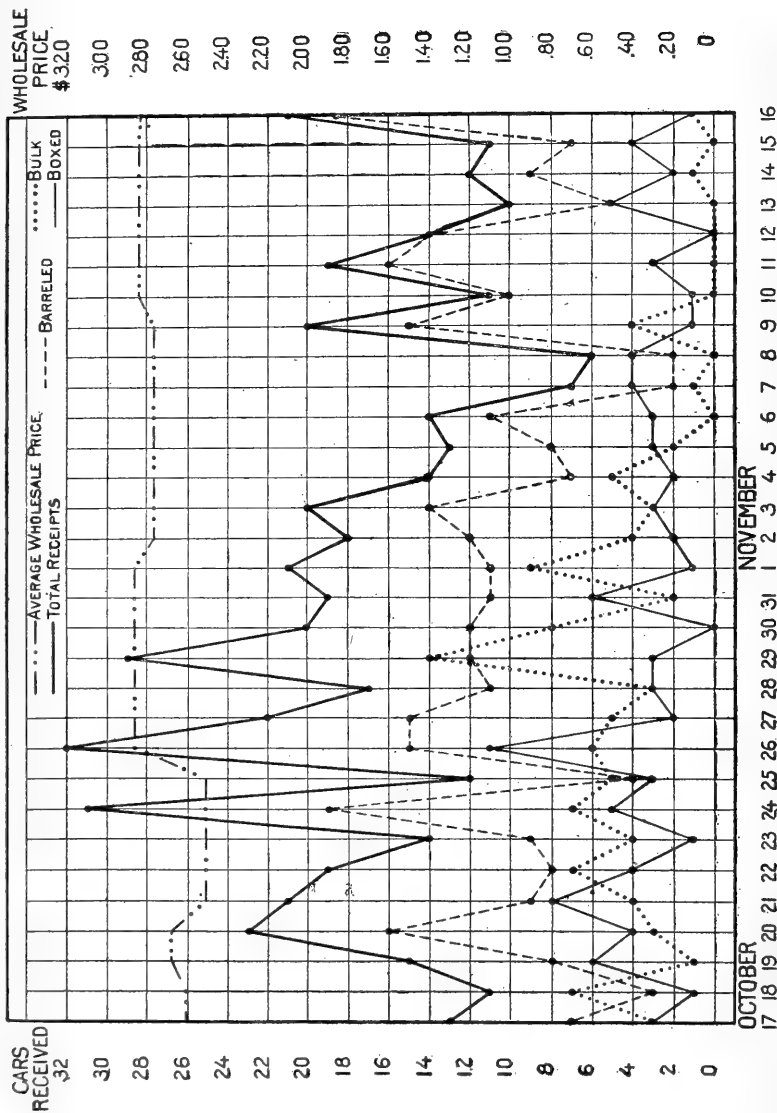
The studies conducted in the markets during the fall of 1914 indicated the need for more strict grading and careful handling, the elimination of culls from the fresh-fruit markets, more intelligent distribution, and the effective operation of cooperative associations. Often when the individual growers act independently in marketing the crops, there is little uniformity in the grading and packing, much poor fruit is shipped, much good fruit is forwarded in overripe condition, and the output of the community is dumped on the markets with little regard for equitable distribution or proper storage conservation.

Better methods are required for profitably marketing the increasingly large apple crop. These methods are provided best by effective cooperative organizations. In those States in which apples are packed in boxes, the growers' associations handle a very large percentage of the output. The quality of their fruit, the uniformity of the pack, and the distribution of the crop far surpass the individual results of the Middle West and East. Unusual difficulties were responsible for the development of cooperative associations in the Far West, and it is thought that the problems of the growers east of the Rocky Mountains are coming to be so great that dire need will require them to organize for the purpose of securing more profitable results.

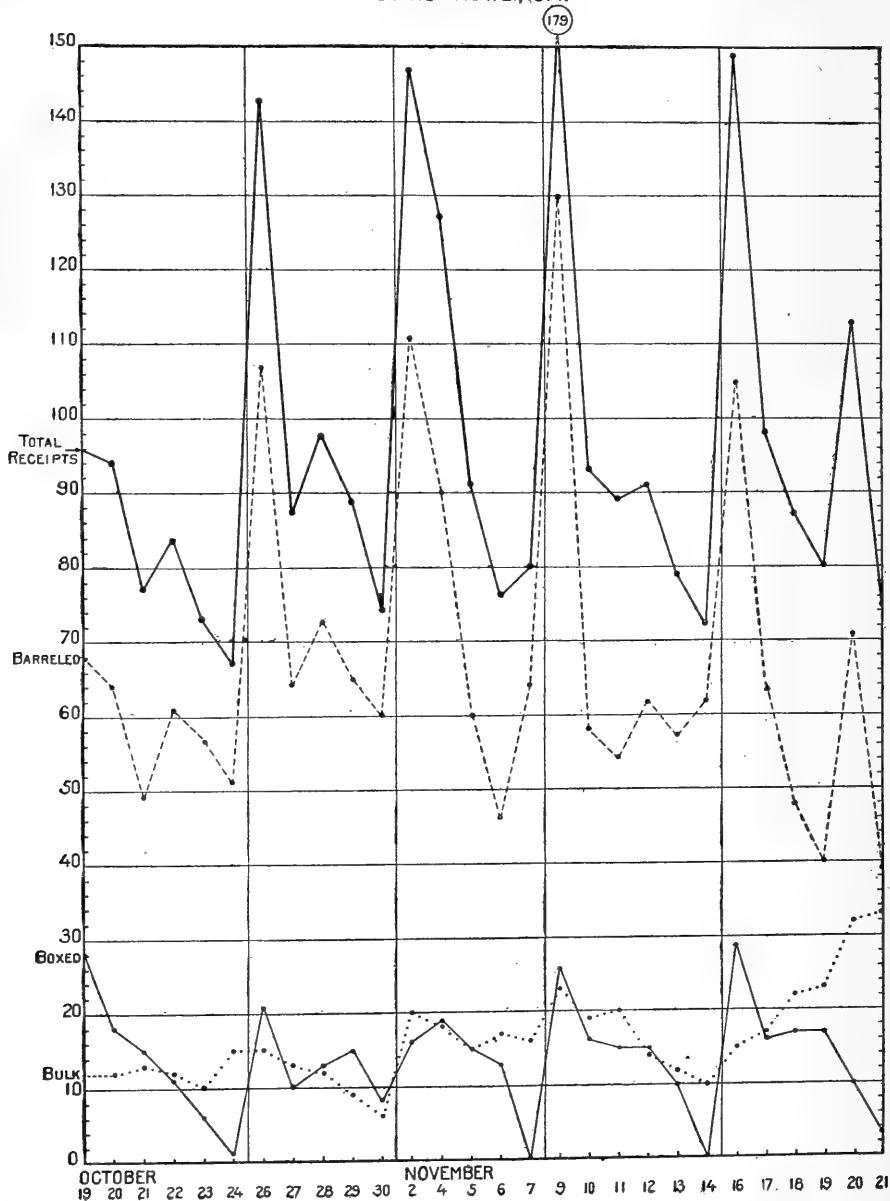
APPENDIX.

The charts included in this Appendix show the daily carlot receipts of barreled, boxed, and bulk apples and the total receipts in the markets of St. Paul and New York City during selected periods in October and November, 1914. Charts 3 to 7 show the total receipts and wholesale prices per barrel of Greening and Baldwin apples in New York City during the 1909-10 season and subsequent seasons to date. Charts 8 to 12 give similar data for York Imperial and Ben Davis apples, in the same market.

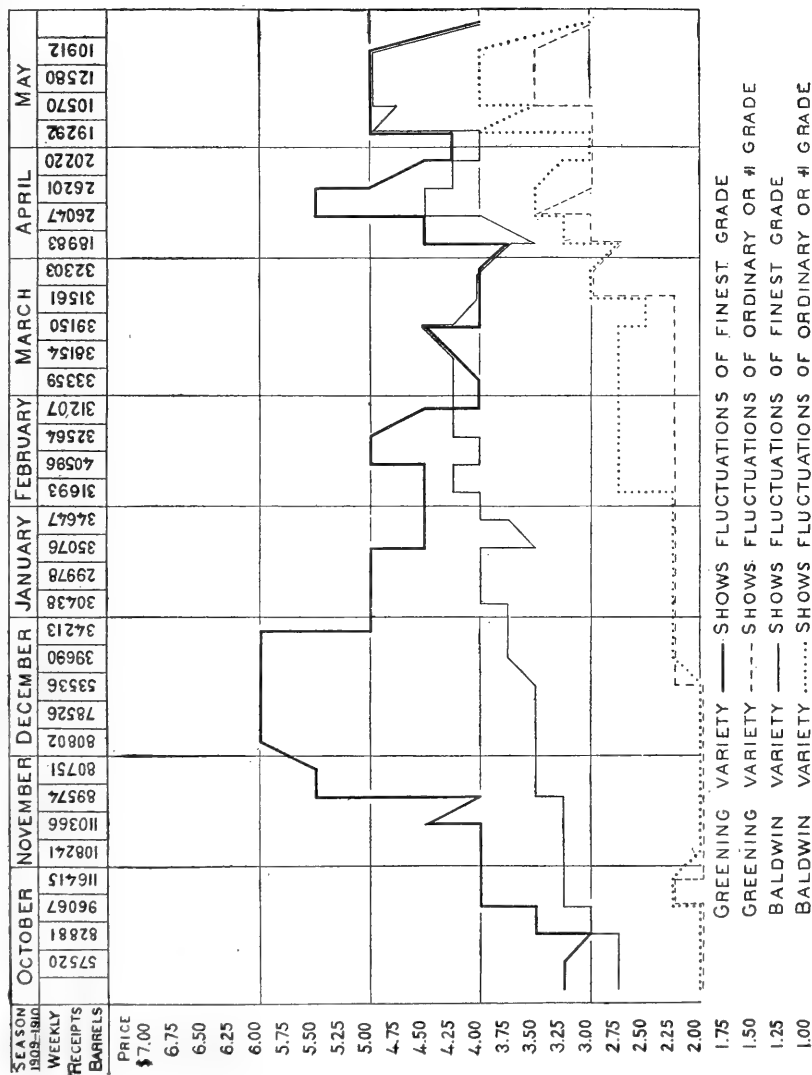
DAILY CAR-LOT RECEIPTS OF BARRELED, BOXED AND BULK APPLES AND TOTAL RECEIPTS AND AVERAGE WHOLESALE PRICE IN ST. PAUL OCT. 17—NOV. 16, 1914



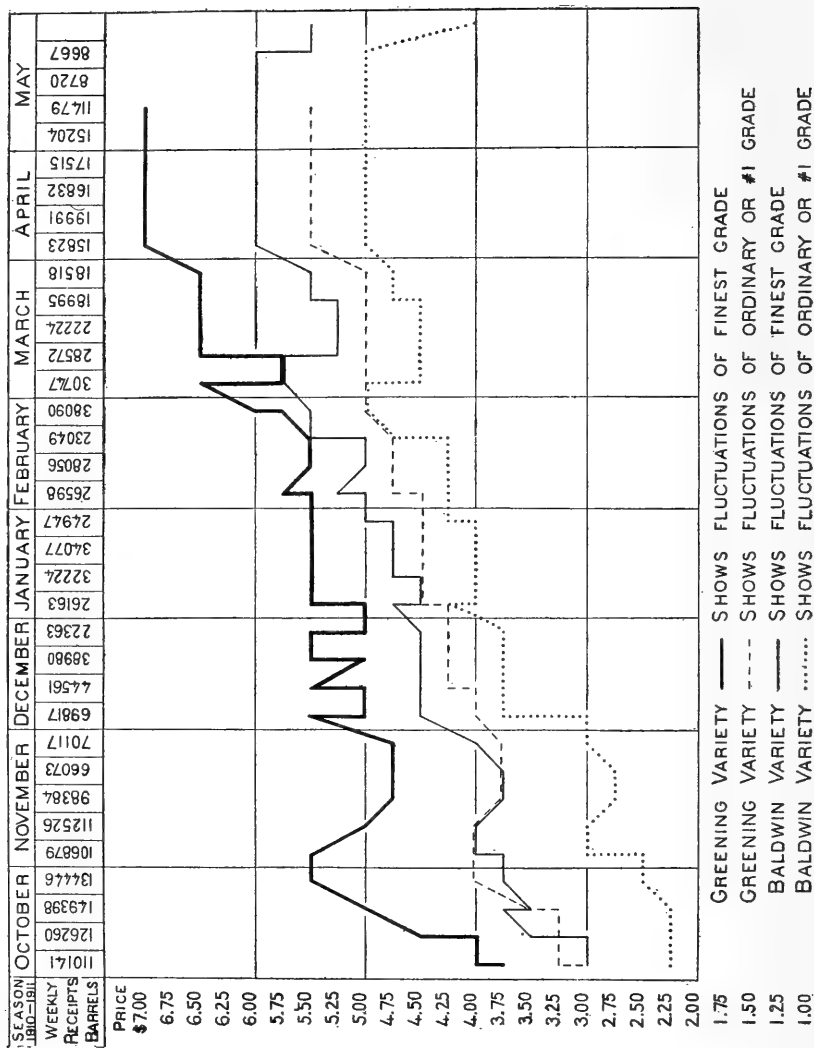
DAILY CAR-LOT RECEIPTS OF BARRELED, BOXED AND BULK APPLES
AND TOTAL RECEIPTS IN NEW YORK CITY
OCT. 19 - NOV. 21, 1914.



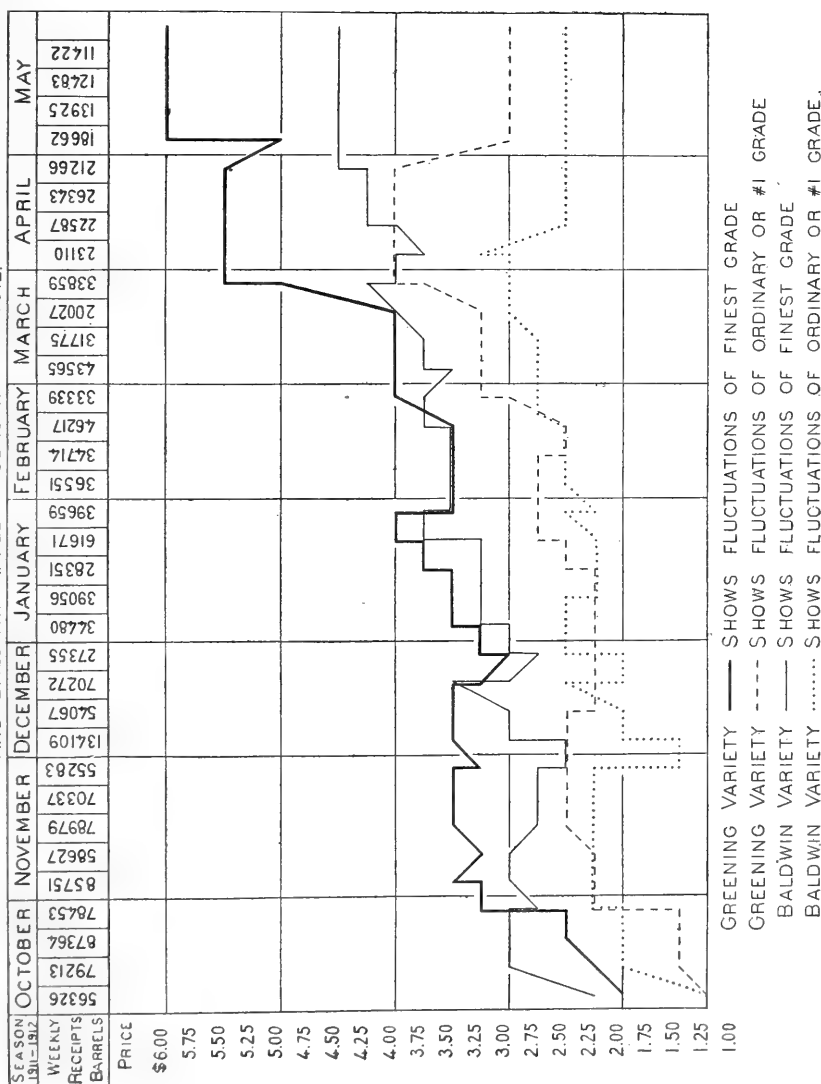
RECEIPTS AND WHOLESALE PRICES PER BARREL IN NEW YORK CITY OF GREENING AND BALDWIN APPLES SEASON 1909—1910



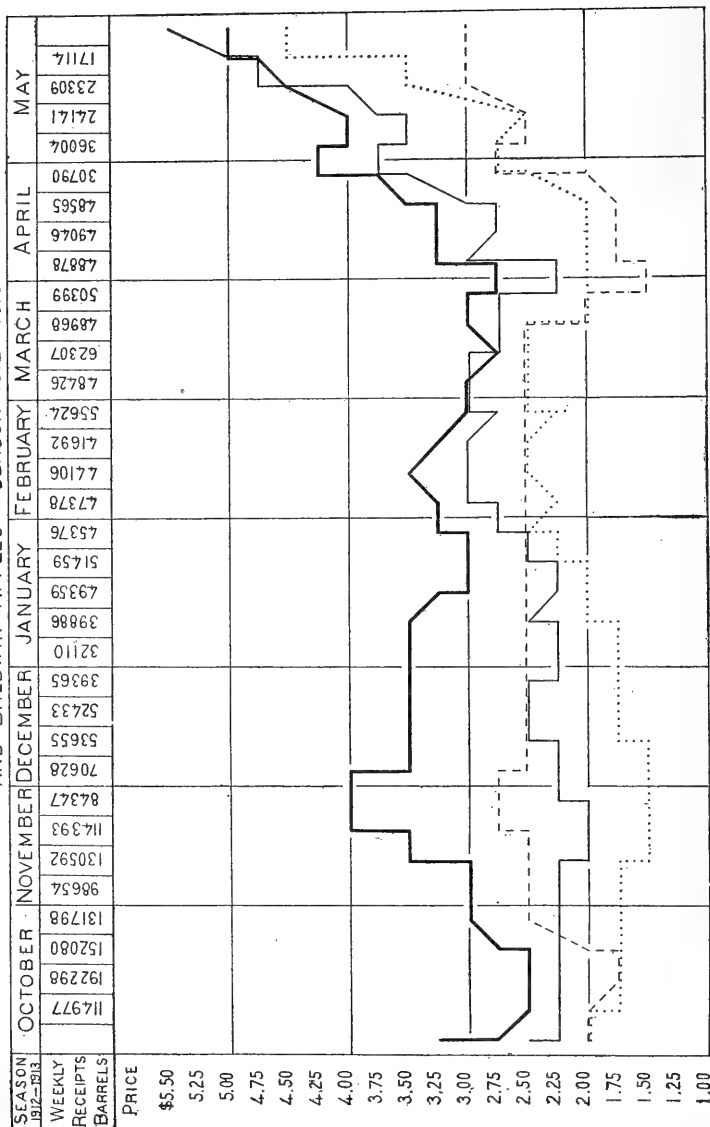
RECEIPTS AND WHOLESALE PRICES PER BARREL IN NEW YORK CITY OF GREENING
AND BALDWIN APPLES SEASON 1910—1911



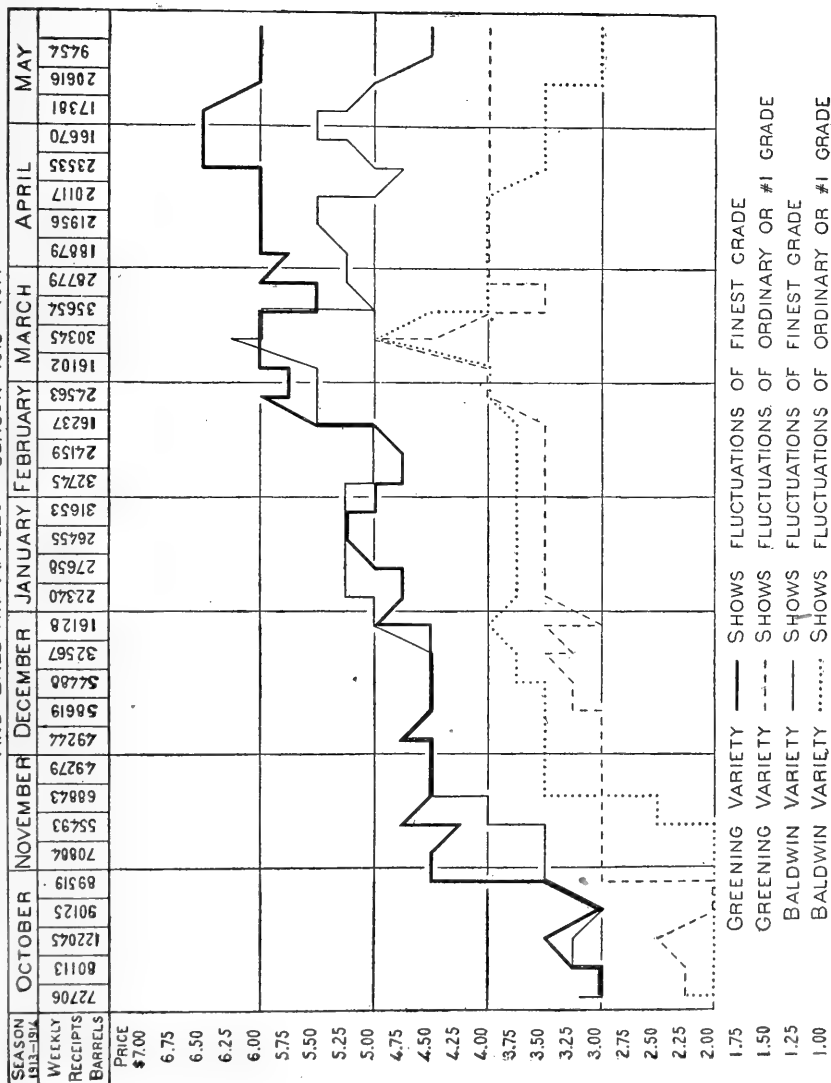
RECEIPTS AND WHOLESALE PRICES PER BARREL IN NEW YORK CITY OF GREENING AND BALDWIN APPLES SEASON 1911—1912.



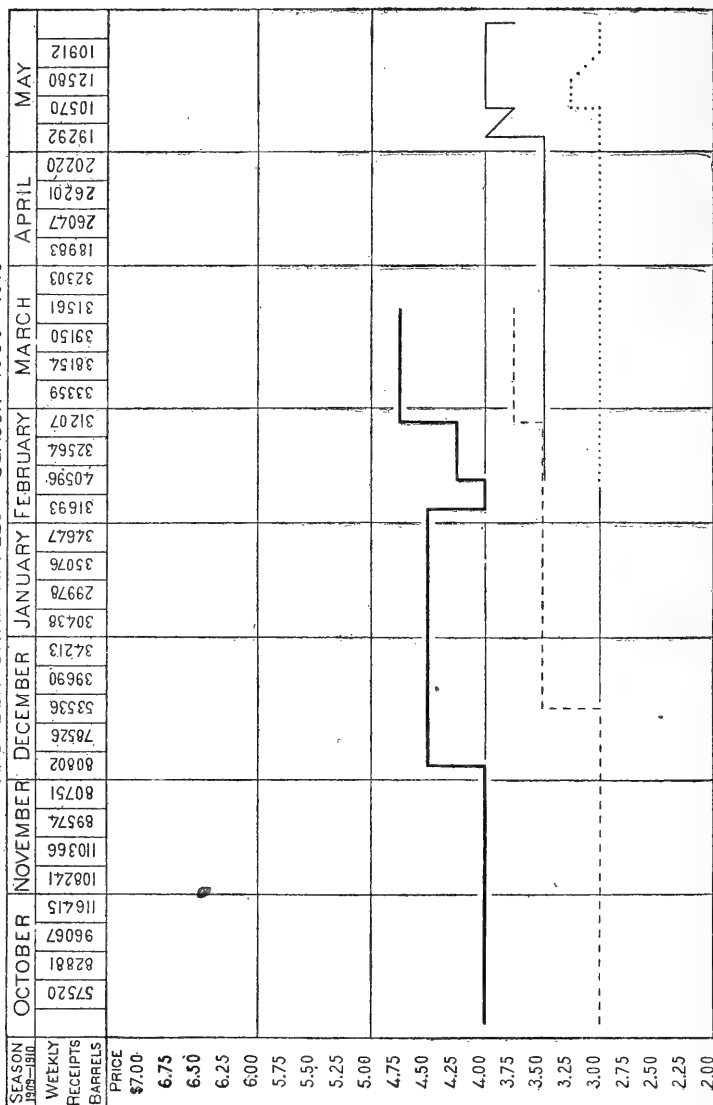
RECEIPTS AND WHOLESALE PRICES, PER BARREL IN NEW-YORK CITY OF GREENING AND BALDWIN APPLES SEASON 1912-1913

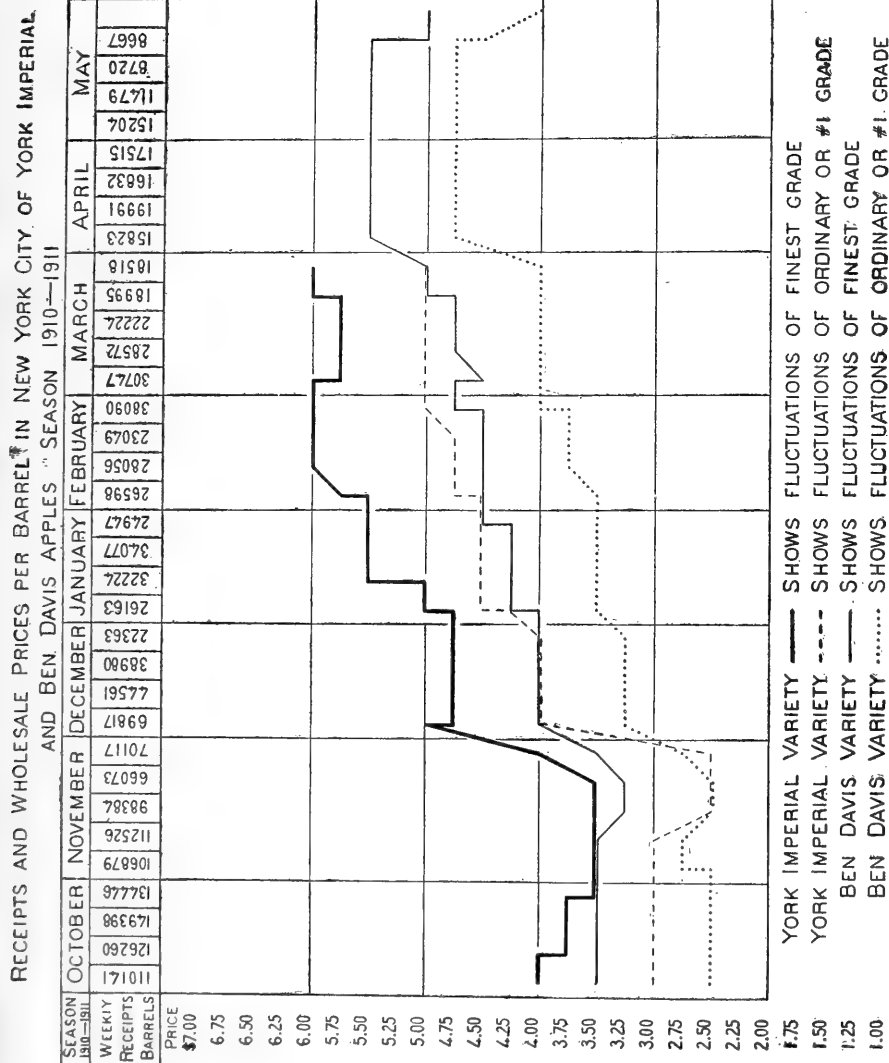


RECEIPTS AND WHOLESALE PRICES PER BARREL IN NEW YORK CITY OF GREENING AND BALDWIN APPLES SEASON 1913-1914

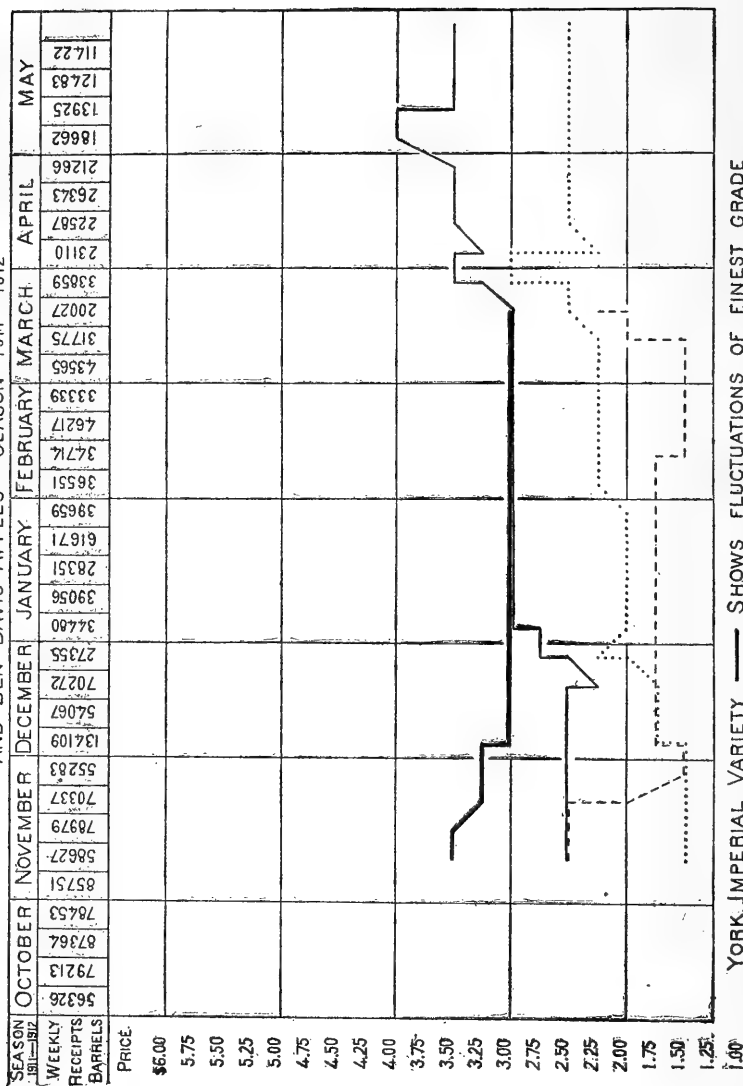


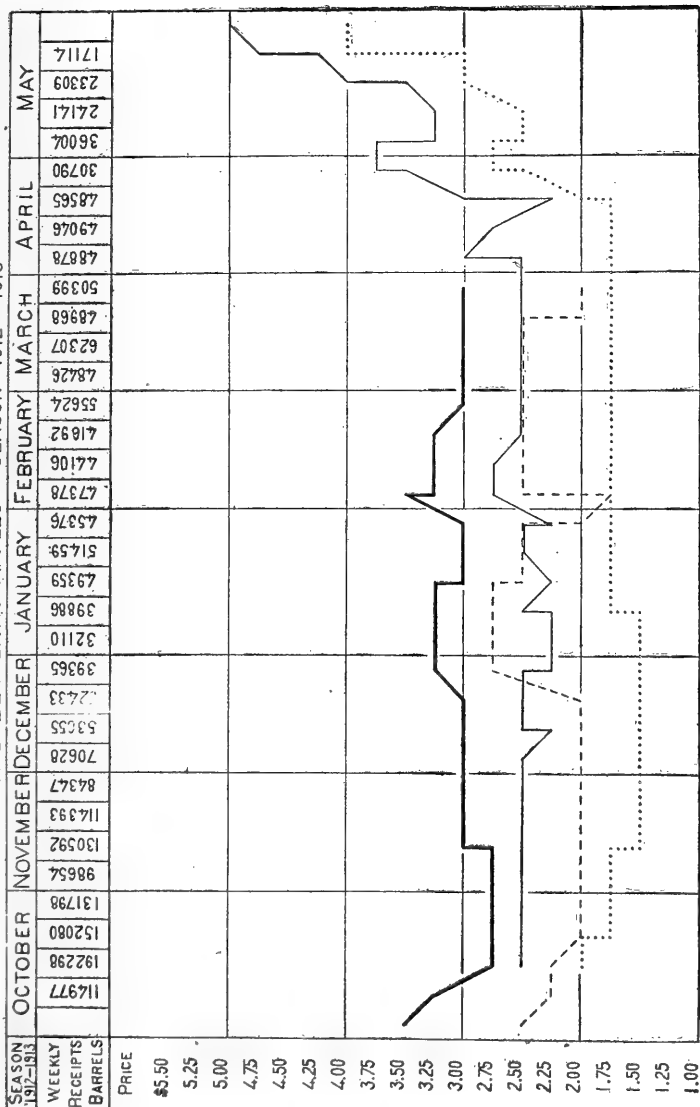
RECEIPTS AND WHOLESALE PRICES PER-BARREL IN NEW YORK CITY OF YORK IMPERIAL
AND BEN DAVIS APPLES SEASON 1909—1910





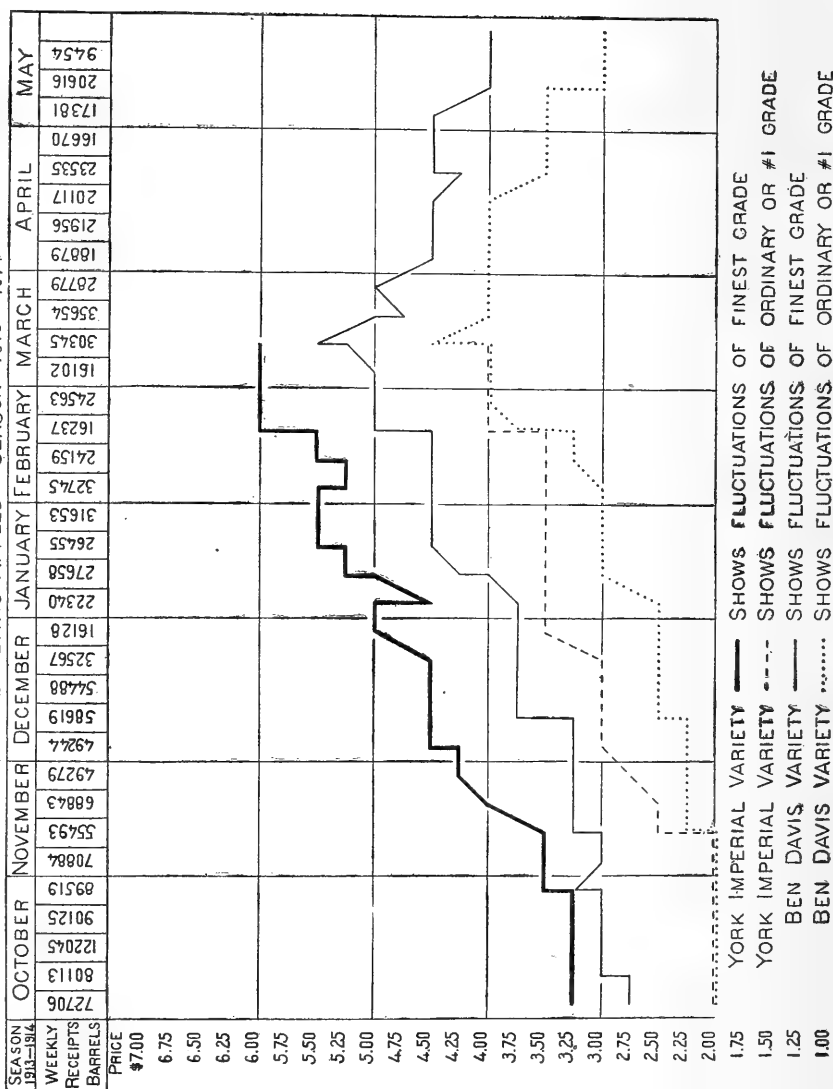
RECEIPTS AND WHOLESALE PRICES PER BARREL IN NEW YORK CITY OF YORK IMPERIAL
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YORK IMPERIAL VARIETY	—	SHOWS FLUCTUATIONS OF FINEST GRADE
YORK IMPERIAL VARIETY	---	SHOWS FLUCTUATIONS OF ORDINARY OR #1 GRADE
BEN DAVIS VARIETY	—	SHOWS FLUCTUATIONS OF FINEST GRADE
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RECEIPTS AND WHOLESALE PRICES PER-BARREL IN NEW YORK CITY OF YORK IMPERIAL AND BEN DAVIS APPLES SEASON 1913-1914



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A BACTERIOLOGICAL STUDY OF RETAIL ICE CREAM.

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INTRODUCTION.

A bacteriological examination of ice cream as the consumer receives it from retail sources is, we believe, the first logical step in the study of the bacteriology of ice cream. The results obtained from the examination of ice cream in this last period of its history will show the final bacterial flora. This type of investigation does not show where the organisms are introduced, but it will show the number and kinds of bacteria present in the cream at the time it is consumed. To determine where these organisms are introduced and their significance is another phase of the general problem.

It is well known that commercial retail ice cream contains large numbers of bacteria. This is well illustrated in a summary of the results of examination of ice cream in various cities, presented in Table 1, taken from a paper by B. W. Hammer.¹ From these figures it is evident that the number of bacteria in ice cream throughout the country averages extremely high.

TABLE 1.—*Summary of Hammer's bacterial investigations of ice cream.*

Source.	Date of investigation.	Number of samples examined.	Bacteria per cubic centimeter.		
			Average.	Highest.	Lowest.
Philadelphia.....	1905-06	49	17,833,031	79,800,000	70,000
Boston.....	1906-07	35	23,000,000	150,000,000	1,000,000
Washington.....	1906-07	263	26,612,371	365,000,000	137,500
Chicago.....	1909	89	16,662,134	125,000,000	20,000
Do.....	1910	306	15,401,000	100,000,000	20,000
Do.....	1911	-----	1,800,000	200,000,000	90,000
Milwaukee.....	1911	26	-----	8,000,000,000	200,000
Des Moines.....	1911	10	19,920,000	39,000,000	4,200,000
Iowa State College.....	1911-12	11	19,775,000	72,000,000	500,000

¹ See bibliography at end of paper.

Bacterial counts, while of value, only tell us the numbers, and this is not sufficient information. It is necessary for a thorough knowledge of the subject to know the kinds of bacteria which are generally present in ice cream as well as the number.

There is relatively little exact information regarding the bacteriology of ice cream, and in consequence probably many applications of the subject to the industry are neglected. Extensive research work on bacteriological problems connected with the manufacture of ice cream is needed, and it is probable that many investigators will devote themselves to this subject when the value of such work is realized.

Our investigations on the general subject of the bacteria of ice cream will be divided into three main parts.

1. A study of the number and kinds of bacteria in commercial retail ice cream as the consumer receives it.
2. A study of the bacteriology of ice cream during manufacture.
3. A study of the development of bacteria in ice cream during storage.

These studies have been undertaken solely with the idea of securing information of fundamental importance relative to the bacteriology of ice cream. We hope by these investigations to be able to give the manufacturer information which will enable him to produce a product of the highest quality.

We believe that bacteriology will be of great value to the manufacturer in controlling the quality of his raw material and the quality of his final product, and in checking the efficiency of the various operations in the production of ice cream.

OBJECTS OF THIS INVESTIGATION.

The first part of our investigations is presented in this paper, the objects of the work being as follows:

1. To determine the number of bacteria in commercial ice cream during the summer and winter seasons.
2. To determine what groups of bacteria are found in commercial ice cream.
3. To determine the relative value of different methods for the determination of *Bacillus coli* in ice cream.

METHODS OF EXAMINATION.

The ice cream was purchased in one-half-pint paper boxes from various stores throughout the city of Washington, D. C. Throughout this paper reference is made to summer and winter samples. The samples of the former were collected from June 20, 1912, to November 11, 1912. Winter samples were obtained during February and March, 1913, the coldest months of the year in Washington. The

samples were taken directly to the laboratory and portions from various parts of each sample were transferred to a sterile Erlenmeyer flask. After the ice cream had melted it was thoroughly shaken to remove as much air as possible and at the same time mix the sample. One cubic centimeter was then plated by the usual methods on plain infusion agar prepared according to standard methods prescribed by the Committee on Standard Methods. The plates were incubated at 30° C. (86° F.) for five days, then counted.

Special methods for the determination of colon bacilli will be discussed later in this paper.

In order to divide the bacteria into groups the "milk-tube method" of differentiation was used. This method, devised by the authors, is fully described in a previous publication.

Briefly described, the milk-tube method consists in picking each colony from an infusion agar plate and inoculating into tubes of litmus milk. The reactions produced in the litmus milk are recorded after 2, 5, and 14 days' incubation at 30° C. (86° F.). Knowing the 14-day reaction produced by bacteria from each colony on the original plate, it is possible to determine the number of bacteria in the original material plated and to divide them into groups, namely, the acid-coagulating, acid-forming, inert, alkali-forming, and peptonizing. An examination of samples collected as mentioned gives the bacterial flora of ice cream just as the consumer would receive it.

THE ACIDITY OF ICE CREAM.

Before entering upon a discussion of the bacteriological results of this work it seems advisable to discuss a few miscellaneous analyses which were made during this study. All the samples of vanilla ice cream were tested for acidity by titration with tenth-normal sodium hydroxid, using phenolphthalein as an indicator. Most of the ice cream of other flavors could not be tested on account of the color. The maximum acidity found was 0.387 per cent and the minimum 0.09 per cent, calculated as lactic acid. The average acidity of 65 samples was 0.206 per cent. Many of the samples were distinctly sour to the taste, and evidently some manufacturers used either old sour cream or else aged the cream in their plants at temperatures sufficiently high to allow lactic-acid bacteria to produce acidity. The acidity did not seem to bear any definite relation to the bacterial count, however, as the samples showing an acidity of 0.387 per cent contained 217,000 bacteria per cubic centimeter, of which 74.51 per cent were acid-forming bacteria, while ice cream with an acidity of 0.09 per cent contained 49,000,000 bacteria per cubic centimeter, of which 89.79 per cent were acid-forming bacteria.

THE NUMBER OF BACTERIA.

Numerous samples of ice cream were purchased from various stores in Washington during the summer and winter season; they represented 24 different manufacturers.¹ Samples representing 11 plants were examined during both seasons. The ice cream from 5 manufacturers was examined during the summer season only, and from 7 plants during the winter season only. In Table 2 are shown the total (average of the two kinds of samples) average counts of ice cream from each plant, together with the average of the samples collected during the summer and winter seasons. It will be seen that only two plants, K₁ and P, out of the 24 showed an average bacterial content of less than 1,000,000 per cubic centimeter. It is possible that if more than one sample had been examined from plant P the average count for that plant would have been more than 1,000,000.

TABLE 2.—Average number of bacteria per cubic centimeter in ice cream from different manufacturers.

Manufacturer.	All samples.		Summer series.		Winter series.	
	Total samples.	Average bacteria per cubic centimeter.	Number of samples.	Average bacteria per cubic centimeter.	Number of samples.	Average bacteria per cubic centimeter.
A.....	32	2,986,187	19	5,008,333	13	416,000
B.....	27	32,007,500	10	31,226,000	17	47,763,529
C.....	19	27,779,631	11	47,909,090	8	101,000
D.....	11	18,836,363	8	26,125,000	3	6,066,666
E.....	9	44,783,333	3	118,000,000	6	8,175,000
F.....	8	5,381,500	3	8,966,666	5	3,230,400
G.....	12	2,580,250	5	6,192,500	7	1,160,428
H.....	5	4,203,600	4	5,207,500	1	188,000
I.....	8	15,487,500	5	18,360,000	3	10,700,000
J.....	3	5,890,000	1	14,100,000	2	1,785,000
K.....	4	265,750,000	4	265,750,000	.....	.....
K ₁ ^a	12	357,583	4	530,000	8	271,375
L.....	4	32,225,000	4	32,225,000	.....	.....
M.....	4	10,910,000	4	10,910,000	.....	.....
N.....	3	5,723,333	3	5,723,333	.....	.....
O.....	6	46,465,000	6	46,465,000	.....	.....
P.....	1	920,000	1	920,000	.....	.....
Q.....	2	19,750,000	.....	.....	2	19,750,000
R.....	1	20,500,000	.....	.....	1	20,500,000
S.....	3	2,463,333	.....	.....	3	2,463,333
T.....	4	3,650,000	.....	.....	4	3,650,000
U.....	2	28,500,000	.....	.....	2	28,500,000
W.....	3	14,700,000	.....	.....	3	14,700,000
X.....	3	17,566,666	.....	.....	3	17,566,666

^a K₁ same plant as K, but there was probably a change in management.

An interesting point is shown in the bacterial averages of ice cream from manufacturers K and K₁. The average bacterial content of ice cream from K was 265,750,000, and from K₁ 357,583 per cubic centimeter. These represent the same plant, but in all probability there was a change in management. We are not certain of this point, but after the four samples were taken from K the condition

¹ Throughout this paper reference is made to samples from different manufacturers or plants, but it must be remembered that the samples were obtained from stores and not at the plants.

of the store was much improved as regards cleanliness, the ice cream no longer contained gelatin, and the bacterial count dropped in a remarkable manner.

When the bacterial averages of the two kinds of samples (summer and winter) are compared it may be seen, by reference to Table 2, that of the samples from 11 plants the bacterial counts averaged decidedly lower during the winter months in every case with the exception of plant B. In that case the average winter count was higher than that of the summer season. Assuming cream to be the greatest source of bacteria in ice cream, we should expect to find the bacterial content of ice cream higher during the summer months. This is probably explained by the lack of proper facilities on the farm for keeping cream cool during the summer, and also by the fact that owing to the increased demand for ice cream during the summer season poor grades of cream are utilized. In the case of plant B, we have no explanation for a higher average bacterial count in winter than in summer unless the cream was aged at the plant for a considerable time at temperatures not sufficiently low to prevent bacterial growth.

In order to show more clearly the comparison of the bacteria in ice cream during the summer and winter seasons, the samples have been grouped in classes according to their bacterial content, as shown in Table 3.

TABLE 3.—*Comparison of bacterial content of summer and winter samples of ice cream.*

Bacteria per cubic centimeter.	Summer.		Winter.	
	Number of samples.	Per cent.	Number of samples.	Per cent.
0 to 50,000.....	0	0	5	5.49
50,001 to 100,000.....	0	0	8	8.79
100,001 to 500,000.....	9	9.57	23	25.27
500,001 to 1,000,000.....	9	9.57	2	2.20
1,000,001 to 5,000,000.....	16	17.03	21	23.08
5,000,001 to 10,000,000.....	12	12.77	5	5.49
10,000,001 to 20,000,000.....	13	13.83	11	12.09
20,000,001 to 30,000,000.....	10	10.64	5	5.49
30,000,001 to 50,000,000.....	8	8.51	3	3.30
50,000,001 to 100,000,000.....	9	9.57	4	4.40
Over 100,000,000.....	8	8.51	4	4.40
Total.....	94	100.00	91	100.00

It may be seen that of 94 samples examined during the summer months, none contained fewer than 100,000 bacteria per cubic centimeter, while of the 91 samples examined during the winter season, 14.28 per cent were lower than 100,000. Of the summer samples, 9.57 per cent contained fewer than 500,000 per cubic centimeter, and of the winter samples 39.55 per cent contained fewer than this number. Of the summer samples 19.14 per cent contained fewer than 1,000,000

per cubic centimeter, while 41.75 per cent of the winter samples contained fewer than 1,000,000 per cubic centimeter. Finally, there remain 80.86 per cent of the summer samples and only 58.25 per cent of the winter samples which contained more than 1,000,000 bacteria per cubic centimeter. These results are shown perhaps

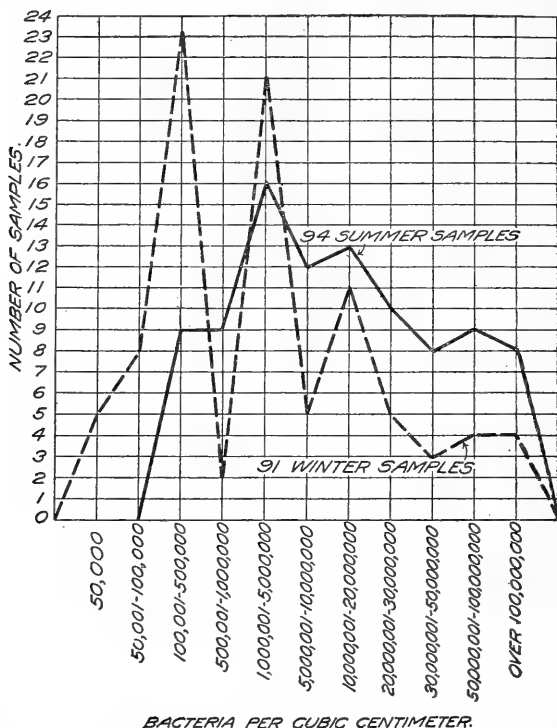


FIG. 1.—Frequency curve showing bacterial content of summer and winter samples of ice cream.

more strikingly in figure 1, where the samples have been plotted in a frequency curve, showing the difference in bacterial content between the summer and winter samples.

The differences in the average counts of ice cream from different manufacturers at different seasons are summarized in Table 4.

TABLE 4.—Summary of the bacterial counts of ice cream.

Item.	Summer series (94 samples).	Winter series (91 samples).
Average number of bacteria per cubic centimeter.....	37,859,907	10,388,222
Maximum number.....	510,000,000	114,000,000
Minimum number.....	120,000	13,000

These figures show a wide range in the bacterial content of ice cream during both the summer and winter months. The minimum counts of 120,000 during the summer and 13,000 in the winter series

furnish evidence that ice cream can be made commercially, at least under some conditions, with a low bacterial content. If these average counts are compared with the average counts from other cities, as shown in Table 1, it will be seen that, so far as bacteria are concerned, the quality of the ice cream is about the same in different localities.

THE GROUPS OF BACTERIA.

THE GENERAL GROUPS.

The bacteria in 71 summer samples and 28 winter samples of ice cream were divided into groups by the milk-tube method of differentiation heretofore mentioned. With this method it was possible,

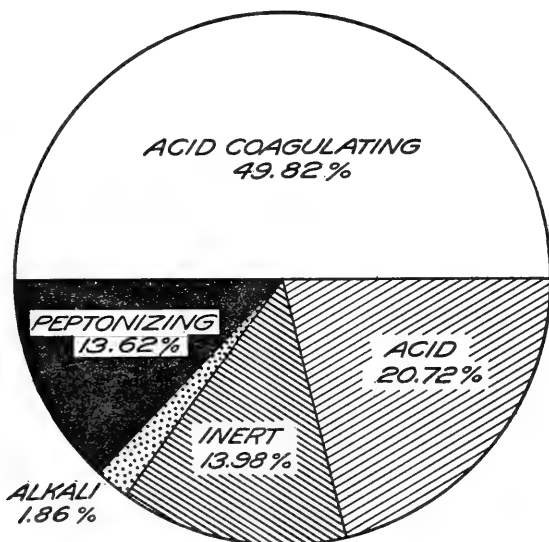


FIG. 2.—Average bacterial groups found in one cubic centimeter of ice cream during the summer months, showing percentages of groups.

Group.	Bacteria per c. c.
Acid-coagulating.....	18,861,805
Acid-forming.....	7,844,575
Inert.....	5,292,815
Alkali-forming.....	704,195
Peptonizing.....	5,156,519
Total.....	37,859,909

on the basis of the 14-day reaction in litmus milk, to divide the bacteria into five groups, namely, acid-coagulating, acid-forming, inert, alkali-forming, and peptonizing. For convenience in obtaining a view of the average groups in an average sample of ice cream, the results are presented graphically. Figure 2 represents 1 c. c. of ice cream and is divided into five sectors, each representing the average percentage of a group of bacteria. The averages are based on the analyses of 71 samples of ice cream examined during the summer season. It may be seen from the figure that the bacteria of 1 c. c. of

an average sample of ice cream during the summer season may be divided into five groups in the following proportions:

	Per cent.
Acid-coagulating group.....	49.82
Acid-forming group.....	20.72
Inert group.....	13.98
Alkali-forming group.....	1.86
Peptonizing group.....	13.62

The total acid group comprises, therefore, 70.54 per cent of the bacteria in the average ice cream during the summer season. In order to make this picture more nearly complete, we have calculated the number of bacteria of each group which would be found in 1 c. c. of an average sample of summer ice cream. These bacterial numbers were obtained by calculation from the average bacterial count of 1 c. c. of ice cream. Since the average commercial ice cream during the summer months contained 37,859,909 per cubic centimeter, the calculated number of each group would be as follows:

	Bacteria per c. c.
Acid-coagulating bacteria.....	18,861,805
Acid-forming bacteria.....	7,844,575
Inert bacteria.....	5,292,815
Alkali-forming bacteria.....	704,195
Peptonizing bacteria.....	5,156,519

Perhaps the most important observation in this connection is the high number of peptonizing bacteria.

In the same manner are shown in figure 3 the bacterial groups in an average sample of winter ice cream. The bacteria may be divided into five groups, as follows:

	Per cent.
Acid-coagulating group.....	30.84
Acid-forming group.....	38.03
Inert group.....	4.81
Alkali-forming group.....	5.42
Peptonizing group.....	20.90

A comparison of the total percentage of the acid groups shows 70.54 per cent during the summer and 68.87 per cent during the winter. It will be seen, however, that during the summer 49.82 per cent were acid-coagulating bacteria, while in the winter only 30.84 per cent were of the acid-coagulating group. The increase in the percentage of the alkali and peptonizing groups is particularly noticeable. From the average group percentages and the average bacterial count the calculated bacterial composition of the 10,388,222 in 1 c. c. of winter ice cream would be as follows:

	Bacteria per c. c.
Acid-coagulating bacteria.....	3,203,728
Acid-forming bacteria.....	3,950,641
Inert bacteria.....	499,673
Alkali-forming bacteria.....	563,042
Peptonizing bacteria.....	2,171,138

A comparison of these figures with those of the average summer samples shows that while the percentages of the alkali and peptonizing groups are higher in winter there were actually smaller numbers of them in ice cream during that season, on account of a lower total number of bacteria during cold weather.

No study was made of the cultural reactions of the bacteria of the various groups, but from our methods of analysis a few points may be brought out.

THE TOTAL-ACID GROUPS.

As we have shown before, of the average bacterial flora of summer ice cream 70.54 per cent is made up of the total group of acid-forming bacteria, and during the winter 68.87 per cent. While using the

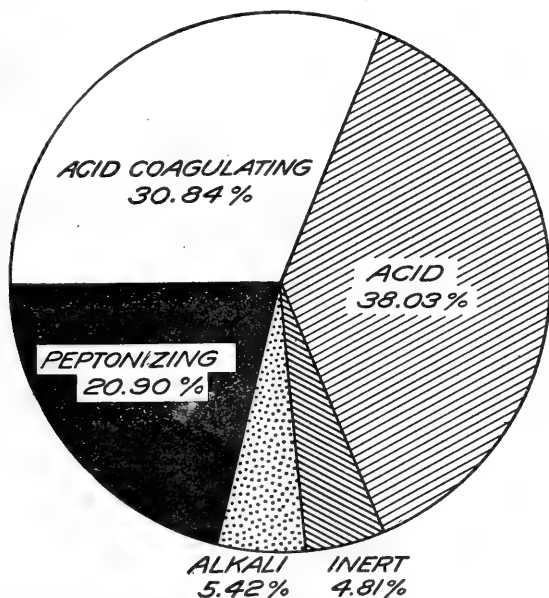


FIG. 3.—Average bacterial groups found in one cubic centimeter of ice cream during the winter months, showing percentages of groups.

Group.	Bacteria per c. c.
Acid-coagulating.....	3,203,728
Acid-forming.....	3,950,641
Inert.....	499,673
Alkali-forming.....	563,042
Peptonizing.....	2,171,138
Total.....	10,388,222

milk-tube method of differentiation the reactions of the litmus milk tubes are recorded after 2, 5, and 14 days, and the total acid-forming group is composed of those bacteria which produce acid in litmus milk during the 14 days of incubation. Those bacteria which form acid and peptonize the milk are included in the peptonizing group. The total-acid group can be further divided into those which produce

acid and coagulate the milk and those which simply form acid within 14 days. Since the reaction is recorded after 2, 5, and 14 days, the rapidity of the growth of the acid-forming bacteria can be determined, and this serves as an additional means of separating the group. In Table 5 the percentages of the acid-coagulating and the simple acid-forming groups of bacteria are shown, based on the 2, 5, and 14 day reaction in litmus milk.

TABLE 5.—*Changes in the percentage of the total-acid group of bacteria in ice cream when determined by litmus-milk reactions after various lengths of incubation.*

Bacterial group.	Per cent reacting after incubation for—		
	2 days.	5 days.	14 days.
Average of 71 summer samples:	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>
Acid-coagulating.....	26.31	41.52	49.82
Acid-forming.....	35.43	25.58	20.72
Average of 28 winter samples:			
Acid-coagulating.....	8.20	25.02	30.84
Acid-forming.....	44.51	41.30	38.03

An examination of the table shows that among the summer samples 49.82 per cent of the bacteria produced acid and coagulated the milk after 14 days. After 2 days 26.31 per cent produced this reaction. This shows that a little more than half, or 52.81 per cent, of the bacteria which were in the ice cream produced the reaction within 48 hours. The remaining 47.19 per cent coagulated milk more slowly and may represent a different variety of acid-forming bacteria. Turning again to the table and considering the acid-coagulating group of the winter series, it will be seen that of the 30.84 per cent which produced the reaction only 8.20 per cent produced acid and coagulated milk in 2 days. Therefore only 26.69 per cent of the acid-coagulating group of the winter samples were active enough to produce the reaction in 48 hours, while 52.81 per cent of this group in the summer samples brought about the change in 2 days.

There is little to be said regarding the acid-forming bacteria which simply produce acid. Many of them grow slowly and do not show an acid reaction for several days in litmus milk. The milk-tube method furnishes a means of determining the difference in the rapidity with which the bacteria produce acid. As may be seen in Table 5, the percentage of the acid-forming group of bacteria was highest when determined by the 2-day reactions and lowest when based on the 5 and 14 day reactions. This is explained by the fact that many bacteria have simply formed acid after two days in litmus milk and later may coagulate or peptonize the milk, and are therefore thrown into another group.

THE INERT GROUP.

The inert group of bacteria in ice cream comprises those which produce no change in litmus milk during the 14 days' incubation at 30° C. (86° F.). By this method of grouping there are, of course, included in the inert group those cultures which fail to grow in milk and tubes of litmus milk, and which would also be included even though the lack of growth were caused by failure to inoculate the tubes properly. However, this last possibility is small. The inert group is of little interest, on the whole, since the bacteria produce no apparent change in milk, and in all probability the same is true of ice cream.

THE ALKALI GROUP.

The alkali-forming group of bacteria is made up of organisms capable of producing an alkaline reaction and no other apparent change in litmus milk during the 14 days' incubation at 30° C. (86° F.). This group does not include bacteria which produce an alkaline reaction together with visible signs of peptonization. While there are in the literature references which deal with types of alkali-forming bacteria, this group has rarely, if ever, been considered when the flora of milk has been under discussion. The authors in some previous work on bacteria in milk showed that considerable numbers of this group were present in milk. In a later piece of work we have shown the numbers of this type of bacteria in milk, together with some of the cultural reactions of the alkali-forming bacteria. These bacteria, however, give very few positive reactions with the usual cultural media, and it is impossible to give much information regarding this group. A detailed bacteriological and chemical study of these organisms is under way in the research laboratories of the Dairy Division.

It will be seen from Table 6 that during the summer series of ice-cream samples the average sample contained 1.86 per cent of the alkali group of bacteria, and during the winter series 5.42 per cent. In general, the alkaline reaction is not noticeable until after four or five days' incubation in litmus milk. Occasionally, however, the reaction is in evidence in 48 hours. The group percentage for the summer season was 1.86 after 14 days and only 0.15 per cent based on the 2-day reaction. Therefore only 8.06 per cent of the bacteria of the alkali group produce an alkaline reaction within 48 hours. Among the samples collected during the winter season only 3.13 per cent of the bacteria of this group were capable of producing the reaction within two days. Whether this indicates a different variety of organism can not be said with assurance.

TABLE 6.—*Changes in the percentage of the alkali group of bacteria in ice cream when determined by litmus-milk reactions after various lengths of incubation.*

Alkali group.	Per cent reacting after incubation for—		
	2 days.	5 days.	14 days.
Average of 71 summer samples.....	<i>Per cent.</i> 0.15	<i>Per cent.</i> 1.03	<i>Per cent.</i> 1.86
Average of 28 winter samples.....	.17	4.00	5.42

At present we are unable to state the significance of this group of bacteria in milk and ice cream, but it is evident that they are not present in ice cream in large numbers, as are the bacteria of other groups. The average numbers of alkali-forming bacteria in ice cream from 16 manufacturers during the summer season and from 7 during the winter season are shown in Table 7.

TABLE 7.—*Average number of alkali-forming bacteria per cubic centimeter of ice cream from various manufacturers.*

Manufacturer.	Summer.		Winter.	
	Number of samples.	Average number of alkali bacteria per cubic centimeter.	Number of samples.	Average number of alkali bacteria per cubic centimeter.
A.....	11	56,945	3	9,192
B.....	3	1,155,327	5	2,326,068
C.....	3	1,739,007	.....	.....
D.....	1	386,000	3	265,545
E.....	3	462,871	.....	.....
F.....	2	340,820	2	14,146
G.....	4	136,198	1	31,815
H.....	1	251,509	.....	.....
I.....	1	1,316,800	.....	.....
J.....	1	902,400	2	93,867
K.....	4	18,348	1	111,377
L.....	1	419,240	.....	.....
M.....	1	22,464	.....	.....
N.....	3	118,219	.....	.....
O.....	1	1,044,900	.....	.....
P.....	1	47,104	.....	.....
Grand average.....	41	526,134	17	407,430
Maximum count.....	.....	2,998,700	.....	10,400,000
Minimum count.....	.....	4,681	.....	1,901

Alkali-forming bacteria were not found in each sample examined, but this does not prove that there were none present in the ice cream. Since these organisms are present in small numbers compared to the rest of the bacteria, it is not surprising that none should be found on plates in which the dilution had to be high in order to take care of the large total number of organisms.

THE PEPTONIZING GROUP.

The peptonizing group is probably the most interesting if not the most important group of bacteria in ice cream. This group consists of what are commonly known as the putrefactive bacteria; that is to say, they attack primarily the proteins, decomposing them into less complex organic bodies. Bacteria of this class are usually considered undesirable in articles of food, and it is to them that intestinal troubles are sometimes attributed, perhaps with or without justification. Whatever their true effect is will not be discussed in this paper, but because bacteria of this group are looked upon with suspicion it is therefore of great importance. In Table 8 will be found the averages of the number of peptonizing bacteria in ice cream during the summer and winter seasons from a number of different plants.

TABLE 8.—Average number of peptonizing bacteria per cubic centimeter of ice cream from various manufacturers.

Manufacturer.	Summer.		Winter.	
	Number of samples.	Average number of peptonizing bacteria per cubic centimeter.	Number of samples.	Average number of peptonizing bacteria per cubic centimeter.
A.....	15	909, 132	3	30, 358
B.....	7	3, 579, 261	7	1, 159, 888
C.....	8	2, 752, 681	2	2, 097
D.....	6	2, 587, 978	3	247, 944
E.....	3	1, 064, 463	.....	.....
F.....	3	1, 018, 440	3	104, 008
G.....	5	567, 409	3	197, 314
H.....	1	328, 119	.....	.....
I.....	1	406, 400	.....	.....
J.....	1	1, 128, 000	.....	.....
K ₁	4	415, 018	2	290, 623
L.....	4	4, 370, 497	2	117, 316
M.....	4	874, 754	.....	.....
N.....	2	72, 253	.....	.....
O.....	3	2, 879, 467	.....	.....
P.....	1	247, 656	.....	.....
Grand average.....	68	1, 449, 533	25	268, 693
Maximum count.....	.....	21, 000, 000	.....	2, 974, 400
Minimum count.....	.....	36, 063	.....	1, 194

The bacterial averages were much higher in the summer than during the winter. It is evident from these figures that the average commercial ice cream contains a large number of peptonizing bacteria. In order to show the range in the percentage of peptonizers, the entire lot of summer and winter samples has been plotted in a frequency curve, as shown in figure 4. It will be seen that the majority of samples contained from 0.1 to 5 per cent of peptonizing bacteria. A large proportion contained, however, as high as 25 to 30 per cent, and in a few samples they were present to the extent of from 90 to 95 per cent of all the bacteria.

Among this group there are a large number of different types of organisms. Many rapidly peptonize the casein of milk and render milk alkaline or slightly acid, while others first attack the lactose and only produce a slight peptonization after several days' growth. From the milk-tube method of differentiation of the bacterial groups it was possible to gain some information as to the extent of these different classes of peptonizers. In Table 9 are shown the average percentages of the peptonizing group in summer and winter samples of ice cream. Based on the 14-day reaction among the summer

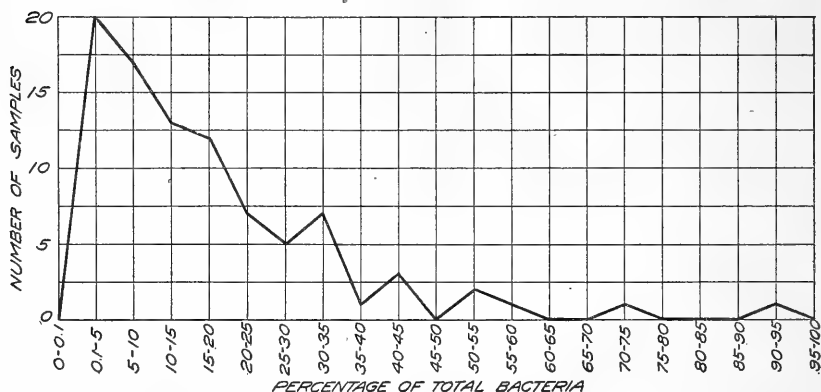


FIG. 4.—Frequency curve showing percentage of peptonizing bacteria per cubic centimeter of ice cream, summer and winter series combined.

samples, 13.62 per cent of the bacteria belonged to the peptonizing group. According to the 2-day reaction, there were 5.93 per cent. Therefore 43.54 per cent of the peptonizing bacteria were sufficiently active to produce a peptonization within two days. Among the winter samples 34.06 per cent of the peptonizing bacteria were sufficiently active to peptonize milk within 48 hours. These active peptonizing bacteria are more important than the slower-acting varieties, since their peptonizing action is usually more complete than that of the latter-named varieties, and if any harm is produced by this group, they are most likely to be the organisms concerned.

TABLE 9.—Changes in the percentage of the peptonizing group of bacteria in ice cream when determined by litmus-milk reactions after various lengths of incubation.

Peptonizing group.	Per cent reacting after incubation for—		
	2 days.	5 days.	14 days.
Average of 71 summer samples.....	Per cent. 5.93	Per cent. 9.76	Per cent. 13.62
Average of 28 winter samples.....	7.12	13.58	20.90

COLON BACILLI IN ICE CREAM.

Since the presence of colon bacilli has been understood in water analysis to indicate fecal contamination, many investigators and boards of health apply the same tests to milk, and naturally then to ice cream with the same idea.

In water analysis lactose-bile fermentation tubes are used for the examination for colon bacilli. By using different dilutions the minimum number of gas-forming bacteria in a given amount of water may be determined. This preliminary test has to be followed by confirmatory tests in which cultures are isolated and their characteristics studied in order to prove the presence of colon bacilli. In our work we have used this method to some extent, but have endeavored to prepare a synthetic medium which would restrict the growth of the majority of bacteria found in ice cream and at the same time would allow colon bacilli to develop and produce characteristic reactions. During the experiments 53 different combinations were used, as shown in Table 10.

Asparagin was used as a source of nitrogen in almost all media. Throughout our work we used medium No. 1, which was made as follows: Agar, 1.5 per cent; asparagin, 0.3 per cent; sodium dibasic phosphate, 0.1 per cent; lactose, 1 per cent; and 2 per cent of a saturated neutral solution of litmus. This medium proved the most satisfactory of all, and when tested with 10 different strains of *Bacillus coli* it was found that they all grew well. Medium No. 13, recommended by Dolt, did not prove satisfactory, as several of the strains of coli did not develop well on this medium. Medium No. 53, composed of agar 1.5 per cent, lactose 1 per cent, ammonium malate 0.2 per cent, sodium acid phosphate 0.02 per cent, and 2 per cent saturated neutral solution of litmus, proved very satisfactory in a few examinations, but as this medium was developed late in the work it has not been thoroughly tested. The value of the other media will not be discussed here but will be reserved for a later continued study of the subject.

When ice cream was plated on litmus-lactose-asparagin agar, colon bacilli proved to be about the only organisms which grew and formed acid. The colonies were quite distinctive in their appearance and with little practice could readily be counted. Occasionally there developed on the plate a few very small acid colonies which were not gas formers, and sometimes a few nonacid-forming colonies were observed. The majority of bacteria in ice cream did not grow on this medium, at least not in 48 hours at 37° C. (97.5° F.), and it was possible to plate as low as one-tenth of a cubic centimeter when 1000000 dilution had to be used with infusion agar.

TABLE 10.—Composition of synthetic media in an attempt to produce a medium suitable for the determination of *Bacillus coli* in ice cream.

[Amounts expressed as percentages.]

Medium No.	Agar.	Asparagin.	Lactose.	Sodium dibasic phosphate.	Potassium dibasic phosphate.	Potassium acid phosphate.	Saturated neutral lithium solution.	Cubic centimeter of 10 per cent alcoholic fuchsin in 1 liter of medium.	Cubic centimeter of 2½ per cent solution of anhydrous sodium sulphite in 1 liter of medium.	Sodium chloride.	Aesculin.	Iron citrate.	Sodium citrate.	Ammonium citrate.	Ammonium sulphite.	Ammonium lactate.	Ammonium sulphate.	Urea.	Phenol.	Casein.	Sodium carbonate.	Pepton.	Ox bile.	Cubic centimeter NaOH N solution.	½ per cent solution neutralized.	1 per cent solution Dahi.	Reaction corrected to—	Remarks. (Reaction not changed unless noted.)
1	1.5									0.5																		
2	1	0.3	1	1	1		2			0.5												0.5						
3	1			1	1		2			0.5																		
4	1			1	1		2			0.5																		
5	1			1	1		2			0.5																		
6	1			1	1		2			0.5																		
7	1			1	1		2			0.5																		
8	1			1	1		2			0.5																		
9	1			1	1		2			0.5																		
10	1			1	1		2			0.5																		
11	1			1	1		2			0.5																		
12	1			1	1		2			0.5																		
13	1.5			1	1		2			0.5																		
14	1.5			1	1		2			0.5																		
15	1.5			1	1		2			0.5																		
16	1.5			1	1		2			0.5																		
17	1.5			1	1		2			0.5																		
18	1			1	1		2			0.5																		
19	1			1	1		2			0.5																		
20	1			1	1		2			0.5																		
21	1			1	1		2			0.5																		
22	1			1	1		2			0.5																		
23	1			1	1		2			0.5																		
24	1			1	1		2			0.5																		
25	1			1	1		2			0.5																		
26	1			1	1		2			0.5																		
27	1.5			1	1		2			0.5																		
28	1.5			1	1		2			0.5																		
29	1.5			1	1		2			0.5																		
30	1.5			1	1		2			0.5																		
31	1.5			1	1		2			0.5																		
32	1			1	1		2			0.5																		
33	1			1	1		2			0.5																		
34	1			1	1		2			0.5																		

1 per cent azolitmin.

25	30	35	40	45	50	55	60	65	70	75	80	85	90	95	100	105	110	115	120	125	130	135	140	145	150	155	160	165	170	175	180	185	190	195	200	205	210	215	220	225	230	235	240	245	250	255	260	265	270	275	280	285	290	295	300	305	310	315	320	325	330	335	340	345	350	355	360	365	370	375	380	385	390	395	400	405	410	415	420	425	430	435	440	445	450	455	460	465	470	475	480	485	490	495	500	505	510	515	520	525	530	535	540	545	550	555	560	565	570	575	580	585	590	595	600	605	610	615	620	625	630	635	640	645	650	655	660	665	670	675	680	685	690	695	700	705	710	715	720	725	730	735	740	745	750	755	760	765	770	775	780	785	790	795	800	805	810	815	820	825	830	835	840	845	850	855	860	865	870	875	880	885	890	895	900	905	910	915	920	925	930	935	940	945	950	955	960	965	970	975	980	985	990	995	1000	1005	1010	1015	1020	1025	1030	1035	1040	1045	1050	1055	1060	1065	1070	1075	1080	1085	1090	1095	1100	1105	1110	1115	1120	1125	1130	1135	1140	1145	1150	1155	1160	1165	1170	1175	1180	1185	1190	1195	1200	1205	1210	1215	1220	1225	1230	1235	1240	1245	1250	1255	1260	1265	1270	1275	1280	1285	1290	1295	1300	1305	1310	1315	1320	1325	1330	1335	1340	1345	1350	1355	1360	1365	1370	1375	1380	1385	1390	1395	1400	1405	1410	1415	1420	1425	1430	1435	1440	1445	1450	1455	1460	1465	1470	1475	1480	1485	1490	1495	1500	1505	1510	1515	1520	1525	1530	1535	1540	1545	1550	1555	1560	1565	1570	1575	1580	1585	1590	1595	1600	1605	1610	1615	1620	1625	1630	1635	1640	1645	1650	1655	1660	1665	1670	1675	1680	1685	1690	1695	1700	1705	1710	1715	1720	1725	1730	1735	1740	1745	1750	1755	1760	1765	1770	1775	1780	1785	1790	1795	1800	1805	1810	1815	1820	1825	1830	1835	1840	1845	1850	1855	1860	1865	1870	1875	1880	1885	1890	1895	1900	1905	1910	1915	1920	1925	1930	1935	1940	1945	1950	1955	1960	1965	1970	1975	1980	1985	1990	1995	2000	2005	2010	2015	2020	2025	2030	2035	2040	2045	2050	2055	2060	2065	2070	2075	2080	2085	2090	2095	2100	2105	2110	2115	2120	2125	2130	2135	2140	2145	2150	2155	2160	2165	2170	2175	2180	2185	2190	2195	2200	2205	2210	2215	2220	2225	2230	2235	2240	2245	2250	2255	2260	2265	2270	2275	2280	2285	2290	2295	2300	2305	2310	2315	2320	2325	2330	2335	2340	2345	2350	2355	2360	2365	2370	2375	2380	2385	2390	2395	2400	2405	2410	2415	2420	2425	2430	2435	2440	2445	2450	2455	2460	2465	2470	2475	2480	2485	2490	2495	2500	2505	2510	2515	2520	2525	2530	2535	2540	2545	2550	2555	2560	2565	2570	2575	2580	2585	2590	2595	2600	2605	2610	2615	2620	2625	2630	2635	2640	2645	2650	2655	2660	2665	2670	2675	2680	2685	2690	2695	2700	2705	2710	2715	2720	2725	2730	2735	2740	2745	2750	2755	2760	2765	2770	2775	2780	2785	2790	2795	2800	2805	2810	2815	2820	2825	2830	2835	2840	2845	2850	2855	2860	2865	2870	2875	2880	2885	2890	2895	2900	2905	2910	2915	2920	2925	2930	2935	2940	2945	2950	2955	2960	2965	2970	2975	2980	2985	2990	2995	3000	3005	3010	3015	3020	3025	3030	3035	3040	3045	3050	3055	3060	3065	3070	3075	3080	3085	3090	3095	3100	3105	3110	3115	3120	3125	3130	3135	3140	3145	3150	3155	3160	3165	3170	3175	3180	3185	3190	3195	3200	3205	3210	3215	3220	3225	3230	3235	3240	3245	3250	3255	3260	3265	3270	3275	3280	3285	3290	3295	3300	3305	3310	3315	3320	3325	3330	3335	3340	3345	3350	3355	3360	3365	3370	3375	3380	3385	3390	3395	3400	3405	3410	3415	3420	3425	3430	3435	3440	3445	3450	3455	3460	3465	3470	3475	3480	3485	3490	3495	3500	3505	3510	3515	3520	3525	3530	3535	3540	3545	3550	3555	3560	3565	3570	3575	3580	3585	3590	3595	3600	3605	3610	3615	3620	3625	3630	3635	3640	3645	3650	3655	3660	3665	3670	3675	3680	3685	3690	3695	3700	3705	3710	3715	3720	3725	3730	3735	3740	3745	3750	3755	3760	3765	3770	3775	3780	3785	3790	3795	3800	3805	3810	3815	3820	3825	3830	3835	3840	3845	3850	3855	3860	3865	3870	3875	3880	3885	3890	3895	3900	3905	3910	3915	3920	3925	3930	3935	3940	3945	3950	3955	3960	3965	3970	3975	3980	3985	3990	3995	4000	4005	4010	4015	4020	4025	4030	4035	4040	4045	4050	4055	4060	4065	4070	4075	4080	4085	4090	4095	4100	4105	4110	4115	4120	4125	4130	4135	4140	4145	4150	4155	4160	4165	4170	4175	4180	4185	4190	4195	4200	4205	4210	4215	4220	4225	4230	4235	4240	4245	4250	4255	4260	4265	4270	4275	4280	4285	4290	4295	4300	4305	4310	4315	4320	4325	4330	4335	4340	4345	4350	4355	4360	4365	4370	4375	4380	4385	4390	4395	4400	4405	4410	4415	4420	4425	4430	4435	4440	4445	4450	4455	4460	4465	4470	4475	4480	4485	4490	4495	4500	4505	4510	4515	4520	4525	4530	4535	4540	4545	4550	4555	4560	4565	4570	4575	4580	4585	4590	4595	4600	4605	4610	4615	4620	4625	4630	4635	4640	4645	4650	4655	4660	4665	4670	4675	4680	4685	4690	4695	4700	4705	4710	4715	4720	4725	4730	4735	4740	4745	4750	4755	4760	4765	4770	4775	4780	4785	4790	4795	4800	4805	4810	4815	4820	4825	4830	4835	4840	4845	4850	4855	4860	4865	4870	4875	4880	4885	4890	4895	4900	4905	4910	4915	4920	4925	4930	4935	4940	4945	4950	4955	4960	4965	4970	4975	4980	4985	4990	4995	5000	5005	5010	5015	5020	5025	5030	5035	5040	5045	5050	5055	5060	5065	5070	5075	5080	5085	5090	5095	5100	5105	5110	5115	5120	5125	5130	5135	5140	5145	5150	5155	5160	5165	5170	5175	5180	5185	5190	5195	5200	5205	5210	5215	5220	5225	5230	5235	5240	5245	5250	5255	5260	5265	5270	5275	5280	5285	5290	5295	5300	5305	5310	5315	5320	5325	5330	5335	5340	5345	5350	5355	5360	5365	5370	5375	5380	5385	5390	5395	5400	5405	5410	5415	5420	5425	5430	5435	5440	5445	5450	5455	5460	5465	5470	5475	5480	5485	5490	5495	5500	5505	5510	5515	5520	5525	5530	5535	5540	5545	5550	5555	5560	5565	5570	5575	5580	5585	5590	5595	5600	5605	5610	5615	5620	5625	5630	5635	5640	5645	5650	5655	5660	5665	5670	5675	5680	5685	5690	5695	5700	5705	5710	5715	5720	5725	5730	5735	5740	5745	5750	5755	5760	5765	5770	5775	5780	5785	5790	5795	5800	5805	5810	5815	5820	5825	5830	5835	5840	5845	5850	5855	5860	5865	5870	5875	5880	5885	5890	5895	5900	5905	5910	5915	5920	5925	5930	5935	5940	5945	5950	5955	5960	5965	5970	5975	5980	5985	5990	5995	6000	6005	6010	6015	6020	6025	6030	6035	6040	6045	6050	6055	6060	6065	6070	6075	6080	6085	6090	6095	6100	6105	6110	6115	6120	6125	6130	6135	6140	6145	6150	6155	6160	6165	6170	6175	6180	6185	6190	6195	6200	6205	6210	6215	6220	6225	6230	6235	6240	6245	6250	6255	6260	6265	6270	6275	6280	6285	6290	6295	6300	6305	6310	6315	6320	6325	6330	6335	6340	6345	6350	6355	6360	6365	6370	6375	6380	6385	6390	6395	6400	6405	6410	6415	6420	6425	6430	6435	6440	6445	6450	6455	6460	6465	6470	6475	6480	6485	6490	6495	6500	6505	6510	6515	6520	6525	6530	6535	6540	6545	6550	6555	6560	6565	6570	6575	6580	6585	6590	6595	6600	6605	6610	6615	6620	6625	6630	6635	6640	6645	6650	6655	6660	6665	6670	6675	6680	6685	6690	6695	6700	6705	6710	6715	6720	6725	6730	6735	6740	6745	6750	6755	6760	6765	6770	6775	6780	6785	6790	6795	6800	6805	6810	6815	6820	6825	6830	6835	6840	6845	6850	6855	6860	6865	6870	6875	6880	6885	6890	6895	6900	6905	6910	6915	6920	6925	6930	6935	6940	6945	6950	6955	6960	6965	6970	6975	6980	6985	6990	6995	7000	7005	7010	7015
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1 Liter,

In order to test the value of this medium as compared with the bile tube method, 43 samples of ice cream were examined. The results are shown in Table 11. It may be seen that the colon count as determined on litmus-lactose-asparagin agar was higher than the number estimated from bile tubes in 41 of 43 samples. In most samples the number determined from the asparagin plates was much higher; in one sample it was 47 times as high as the number calculated from bile tubes.

TABLE 11.—*Comparison of the number of Bacillus coli in ice cream determined by the bile-tube method and on litmus-lactose-asparagin-agar plates.*

Sample No.	Bile medium.	Litmus-lactose-asparagin-agar plates.				Sample No.	Bile medium.	Litmus-lactose-asparagin-agar plates.			
	B. coli.	B. coli.	Cultures picked.	Cultures picked which form gas in lactose broth.	Per cent gas formers.		B. coli.	B. coli.	Cultures picked.	Cultures picked which form gas in lactose broth.	Per cent gas formers.
1	.....	15,400	154	146	94.80	23	5,000	108,000	.....	.....	.....
2	.....	86,000	80	78	97.50	24	50,000	120,000	.....	.....	.....
3	50	200	.....	.....	.....	25	5,000	75,000	.....	.....	.....
4	(1) 0	100	1	1	100.00	26	100,000	300,000	.....	.....	.....
5	500	8,000	8	8	100.00	27	100,000	600,000	.....	.....	.....
6	500	900	9	9	100.00	28	1,000	47,000	.....	.....	.....
7	1,000	2,500	22	22	100.00	29	250	5,600	.....	.....	.....
8	5,000	13,000	12	12	100.00	30	1,000	6,500	.....	.....	.....
9	750	2,900	29	29	100.00	31	100	1,200	.....	.....	.....
10	2,500	5,600	53	51	98.01	32	2,500	15,000	.....	.....	.....
11	1,000	7,200	62	57	91.93	33	500	3,000	.....	.....	.....
12	250	400	4	4	100.00	34	500	3,000	.....	.....	.....
13	1,000	12,000	12	11	91.61	35	250	1,730	.....	.....	.....
14	2,500	11,900	86	80	93.02	36	75	550	.....	.....	.....
15	7,500	123,000	91	85	93.29	37	1,000	2,530	.....	.....	.....
16	75	3,000	3	3	100.00	38	250	2,350	.....	.....	.....
17	50	3,900	39	34	87.17	39	75	20	.....	.....	.....
18	750	39,000	38	38	100.00	40	50	(2) 0	.....	.....	.....
19	250	5,000	5	5	100.00	41	75	100	.....	.....	.....
20	750	2,400	.....	.....	.....	42	100	230	.....	.....	.....
21	1,000	7,700	.....	.....	.....	43	750	820	.....	.....	.....
22	250	2,400	.....	.....	.....						

¹In $\frac{1}{100}$ dilution.

²In $\frac{1}{10}$ dilution.

TABLE 12.—*Bacteria of the colon group found in ice cream as determined on litmus-lactose-asparagin agar.*

Sample No.	Manu- fac- turer.	B. coli per cubic centi- meter.	Sample No.	Manu- fac- turer.	B. coli per cubic centi- meter.	Sample No.	Manu- fac- turer.	B. coli per cubic centi- meter.
32	A	120	160	C	10	49	K	120,000
33	A	86,000	161	C	30	50	K	75,000
37	A	100	186	C	140	51	K	300,000
38	A	100	187	C	700	79	K ¹	150
39	A	8,000	188	C	50	80	K ¹	40
40	A	900	44	D	2,400	81	K ¹	30
83	A	420	45	D	7,700	82	K ¹	40
124	A	80	89	D	4,600	134	K ¹	10
125	A	10	52	E	600,000	135	K ¹	20
138	A	10	53	E	47,000	136	K ¹	10
139	A	10	54	E	5,600	137	K ¹	10
143	A	10	140	E	30	70	M	1,730
151	A	10	141	E	10	71	M	550
152	A	40	142	E	400	72	M	2,530
153	A	10	67	F	3,900	73	M	2,350
168	A	50	68	F	3,900	84	O	7,600
169	A	30	69	F	5,000	87	O	12,200
31	B	15,400	146	F	100	62	L	11,900
41	B	2,500	147	F	10	63	L	3,000
42	B	17,100	74	G	20	64	L	3,000
43	B	2,800	75	G	10	65	L	123,000
126	B	300	76	G	100	66	P	3,000
127	B	100	77	G	230	144	Q	20
128	B	200	78	G	820	145	Q	20
133	B	1,000	148	G	120	132	R	10
158	B	2,900	149	G	50	175	S	300
162	B	10	150	G	200	176	S	800
163	B	400	59	H	6,500	177	S	600
164	B	700	60	H	1,200	171	T	90
165	B	10	61	H	15,000	172	T	800
166	B	1,400	157	H	10	173	T	1,200
167	B	1,800	55	I	5,600	174	T	100
170	B	14,000	56	I	7,200	178	U	1,400
46	C	700	57	I	400	179	U	4,000
47	C	2,400	58	I	12,000	180	W	2,700
85	C	13,300	154	I	10	181	W	300
86	C	13,500	155	I	900	182	W	700
90	C	6,000	156	I	300	183	X	4,100
91	C	8,300	88	J	3,100	184	X	30
159	C	40	48	K	108,000	185	X	300

¹ In $\frac{1}{10}$ dilution.

During this series of examinations the suspected colon colonies on the asparagin-agar plates from 19 samples were picked off and inoculated into lactose-broth fermentation tubes. After incubation for 48 hours at 37° C. (97.5° F.) the tubes were examined for the presence of gas. The number of cultures picked off and the number showing gas, together with the percentage of the cultures suspected of being gas formers from the examination of the plate, are shown in Table 11. An examination of the results shows that in 10 of the 19 plates studied all the colonies considered gas formers developed gas in fermentation tubes. In other words, 100 per cent were gas formers. Among the other 9 samples the percentage ranged from 87.17 to 100 per cent. This shows that it is possible to detect quite accurately any colonies of gas-forming bacteria on litmus-lactose-asparagin agar.

One hundred and twenty samples of ice cream were examined during the summer and winter seasons by the use of the above-mentioned medium. The results are tabulated in Table 12. Gas-forming

bacteria were present in 106, or 88.33 per cent, of the samples, and absent in one-tenth of a cubic centimeter in 14, or 11.67 per cent, of the samples. Of the 14 negative samples, 13 were of the winter series and the other one was examined during October. The number of gas formers ranged from 10 to 600,000 per cubic centimeter. Among the entire number of samples the average number of gas-forming bacteria was 16,298 per cubic centimeter. Of the 57 summer samples, the average was 29,544. The winter samples showed an average of 889 gas formers per cubic centimeter. Apparently ice cream contains a far greater number of colon bacilli during the summer months than in the winter season.

The question naturally arises, Does this asparagin agar bring out all the gas-forming or colon bacilli? To gain some information on this point a comparison of this medium was made with Endo's medium, which is highly recommended by some authorities for the determination of the colon bacillus. The Endo medium was prepared according to the directions given by Kinyoun and Dieter.

TABLE 3.—*Comparison of colon counts on litmus-lactose-asparagin agar and on Endo's medium.*

Sample No.	Number of B. coli.		Sample No.	Number of B. coli.	
	Litmus-lactose-asparagin agar.	Endo's medium.		Litmus-lactose-asparagin agar.	Endo's medium.
1	90	125,000	10	2,700	11,000
2	800	75,000	11	300	10,000
3	1,200	98,000	12	700	12,000
4	100	25,000	13	30	5,700
5	300	92,000	14	300	11,400
6	800	3,000	15	140	600
7	600	92,000	16	700	2,200
8	4,000	39,000	17	50	1,200

As shown in Table 13, the number of colon bacilli determined in litmus-lactose-asparagin agar was decidedly lower than when Endo's medium was used. It was then a question of what percentage of the colonies on Endo plates called colon bacilli were generally gas formers. To determine this percentage typical colonies were picked off from six Endo plates. Inoculations were made in lactose-broth fermentation tubes and the presence of gas recorded after 48 hours' incubation at 37° C. (97.5° F.). The percentage of the gas-forming cultures from colonies which would be called colon colonies is shown in Table 14.

TABLE 14.—*Cultures picked from Endo's plates showing the number of gas formers.*

Endo plate.	Colonies picked.	Cultures showing gas in lactose broth.		
		Gas+	Gas—	Gas+
	<i>Number.</i>	<i>Number.</i>	<i>Number.</i>	<i>Per cent.</i>
1.....	160	91	69	56.87
2.....	32	7	25	21.87
3.....	73	69	4	94.52
4.....	9	1	8	11.11
5.....	10	0	10	.00
6.....	21	16	5	76.19

From one plate, of the 10 colonies picked off, none produced gas in lactose broth. Of 160 cultures from suspected colon colonies from sample 1 only 56.87 per cent were gas formers. In sample 3 a high percentage—that is, 94.52 per cent of cultures—were gas formers. It is evident that in many cases it is impossible to count the typical colonies on Endo plates and say that they represent gas formers or colon bacilli. Typical colon bacilli are supposed to form on Endo's agar medium-sized colonies which are distinctly red and have a metallic sheen, but doubtless the appearance of colon colonies is quite variable. In a study of the colonies of 10 different strains of *Bacillus coli* on Endo's plates it was found that many of the colonies showed no metallic sheen. Some were pinkish instead of red; there was a red coloration of the medium around some colonies and none around others, and many of the colonies were very small. We also found that a number of nongas-forming bacteria of the acid group and some peptonizers would grow readily on Endo's medium, and the colonies had all the appearance of those of some of the 10 strains of *B. coli* used during these experiments. It must be conceded, however, that a much larger number of gas-forming bacteria can be found in ice cream when using Endo's medium than when plating on litmus-lactose-asparagin agar, and the asparagin plates showed a much higher number than the lactose-bile tubes. The use of Endo's medium for the determination of colon bacilli in ice cream is complicated by the fact that bacteria other than gas formers may give the typical reaction of the colon bacilli; also because when a dilution low enough to determine the number of *B. coli* is used the plate is sometimes overgrown by other bacteria which are present in large numbers.

It is not the purpose of this paper to discuss the best method for the determination of *B. coli* in ice cream, for the reason, which is obvious, that an entirely satisfactory method has not yet been perfected. Each process has its merits and objectionable features, but in view of our present knowledge of the colon group of bacteria it is impossible to say that any one method is the best.

SUMMARY AND CONCLUSIONS.

Samples of ice cream as sold at retail were examined in Washington during the summer season from June 20 to November 11, 1912, and also during the winter season in February and March of 1913.

1. The average acidity of 65 samples of vanilla ice cream examined during the summer and winter season was 0.206 per cent, calculated as lactic acid. The maximum acidity was 0.387 per cent, the minimum 0.09 per cent. No definite relation was found between acidity and the bacterial count.

2. The average number of bacteria found in 94 samples of ice cream examined during the summer months was 37,859,907 per cubic centimeter. The maximum count was 510,000,000, the minimum 120,000. Of the 91 samples examined during the winter months the average count was 10,388,222, the maximum 114,000,000, and the minimum 13,000 bacteria per cubic centimeter. Among the 94 summer samples none contained fewer than 100,000 bacteria per cubic centimeter, while 14.28 per cent of the 91 winter samples were lower than 100,000. Of the summer samples 9.57 per cent contained fewer than 500,000 per cubic centimeter, and of the winter 39.55 per cent contained less than that number. Of the summer samples, 19.14 per cent contained fewer than 1,000,000 per cubic centimeter, while 41.75 per cent of the winter samples contained fewer than that number and 80.86 per cent of the summer samples and 58.25 per cent of the winter samples contained more than 1,000,000 bacteria per cubic centimeter. There was a wide range in the bacterial content during the summer and winter seasons, and with one exception, the average number of bacteria in ice cream from each manufacturer was distinctly lower during the winter months.

3. The bacteria in 71 summer samples and 28 winter samples were divided into groups by the milk-tube method. The percentages of the various groups of bacteria, together with the calculated number of bacteria in each group in an average sample of ice cream examined during the summer and winter seasons, are summarized in the following table:

TABLE 15.—*Summary of bacteria in ice cream.*¹

Bacterial groups.	Summer samples.		Winter samples.	
	Average number of bacteria per cubic centimeter.	Average group percentage.	Average number of bacteria per cubic centimeter.	Average group percentage.
Acid-coagulating.....	18,861,805	49.82	3,203,728	30.84
Acid-forming.....	7,844,575	20.72	3,950,641	38.03
Inert.....	5,292,815	13.98	499,673	4.81
Alkali-forming.....	704,195	1.86	563,042	5.42
Peptonizing.....	5,156,519	13.62	2,171,138	20.90
Total.....	37,859,909	100.00	10,388,222	100.00

¹ The counts were made from the average percentage of each group and the average total count.

The bacterial groups bore much the same relation to each other in the average summer and winter samples. There was, however, in the summer samples a higher percentage of the acid-coagulating group of bacteria and a lower percentage of the alkali and peptonizing groups than in the winter samples. In spite of a higher percentage of the two groups last named in the average winter sample, the number of bacteria of these was much lower, owing to a lower average total bacterial count.

4. Among the summer samples of ice cream 52.81 per cent of the bacteria of the acid-coagulating group were active enough to coagulate milk in 48 hours when incubated at 30° C. (86° F.). The remaining 47.19 per cent coagulated milk more slowly and may represent a different variety of acid-forming bacteria. Only 26.69 per cent of the acid-coagulating group of bacteria in the winter samples coagulated in 48 hours. There is therefore a higher percentage of rapid acid-coagulating bacteria in ice cream during the summer months.

5. The average number of peptonizing bacteria found in the summer samples of ice cream was 1,449,533. The maximum count was 21,000,000, the minimum 36,063, peptonizing bacteria per cubic centimeter. During the winter season the average number was 268,693, which is about one-fifth the average summer count. The maximum number was 2,974,400 and the minimum 1,194 bacteria per cubic centimeter. The majority of the samples during the entire investigation contained from 0.1 to 5 per cent of peptonizers. A large proportion contained as high as 25 to 30 per cent, and in a few samples they were present to the extent of from 90 to 95 per cent of the total bacteria. Among the summer samples 43.54 per cent of the peptonizing bacteria were sufficiently active to produce a peptonization in milk within 48 hours at 30° C. (86° F.), while 34.06 per cent of these bacteria in the winter samples were able to produce this change in the same time. It is probable that these active peptonizers are more important than the slower-acting varieties, since they usually produce a greater decomposition of the milk.

6. Gas-forming bacteria of the colon-aerogenes group when determined on litmus-lactose-asparagin agar were found present in one-tenth of a cubic centimeter in 106, or 88.33 per cent, of the 120 samples examined, and absent in one-tenth of a cubic centimeter in 14, or 11.67 per cent, of the samples. Of the 14 negative samples, 13 were of the winter series and 1 was examined during October. The average number of gas formers in the entire series of samples was 16,298 per cubic centimeter. Fifty-seven samples examined during the summer averaged 29,544 per cubic centimeter. The 49 winter samples contained an average of 889 per cubic centimeter. Ice cream contained a much larger number of gas-forming organisms during the summer season. A large number of media were used in an attempt

to devise a suitable medium for the detection of *Bacillus coli* in ice cream, and our results show that there is no entirely satisfactory method known at present.

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LAND DRAINAGE BY MEANS OF PUMPS.

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[Revised with special reference to the Upper Mississippi Valley by C. W. Okey, Senior Drainage Engineer.]

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INTRODUCTION.

The drainage of low-lying lands by the use of pumping machinery to lift the drainage water over levees into adjacent streams or other drainage channels is a recent development in this country. Along the banks of many of our larger interior rivers considerable areas of bottom land are subject to overflow from the adjacent streams during the high water occurring usually with great regularity throughout the spring and early summer months. Such lands in their native state do not become dry enough to be subject to ordinary cultural operations until well toward the middle of the summer, and

NOTE.—This bulletin treats in general of the drainage of land which lies so low that it must be protected from overflow by levees and the drainage water pumped out of the protected area owing to lack of gravity outlet. The bulletin has special reference to low-lying bottom lands along the larger streams of the upper Mississippi Valley.

hence can not generally be used for growing ordinary crops. In this natural condition they are, therefore, good for nothing but pasture, and have accordingly but little agricultural value.

Similarly, extensive marshy areas along our coasts may be for a part of the time above water level, but are subject to overflow at high tide, especially during spring tides and when the river channels which form their natural drainage outlets are in flood. All such low lands are, in general, formed by alluvial deposit and possess a high degree of fertility when relieved of their excess of water and changed from their original saturated condition to a degree of moisture content suitable for ordinary dry-land crops.

As a physical proposition it is possible to reclaim all such areas for agriculture by first constructing levees to keep them from being overflowed, and then, where necessary, by installing pumping plants to pump out from the interior of the district the excess rainfall and such water as may seep through or under the levees in injurious amounts. But as such work is expensive both for the first construction and for its subsequent maintenance and operation, the really difficult and fundamental question for the landowner is whether the value of the land after its reclamation will be sufficient to justify the expenditures necessary to carry out the work.

So long as there exists in a locality any unoccupied or unutilized higher land suitable for agriculture there is little demand for the use of lands lying so low as to require drainage by pumps. But the present high price of agricultural land justifies a heavy expenditure for the conversion to a productive state of areas formerly considered almost valueless, especially in those regions where agricultural land values are particularly high, either on account of unusually favorable natural conditions or the proximity of large centers of population.

EFFECTIVENESS OF DRAINAGE RECLAMATION.

Some areas are so favorably situated that, when once protected by levees from inundation, satisfactory interior drainage without the use of pumps may be secured by a natural or gravity flow of their drainage waters, either through sluice gates or through ditches or natural streams other than those producing the overflow. Examples of such lands are many tidal marshes and the large areas in Arkansas, Mississippi, and northern Louisiana, where the land, protected from the Mississippi River by great levees, has good gravity drainage outlets through other streams.

But much overflowed land is not so fortunately located. Frequently, in addition to a protective levee system, a pumping plant is required for lifting the interior drainage water out over the levee. In fact, numerous cases may be found in which, when the levee system was first constructed, reliance was placed solely upon gravity

outlets for disposing of the interior drainage water, but subsequent experience showed that by this means alone satisfactory reclamation of the land could not be secured; hence, a supplementary pumping plant, not contemplated in the original plans, was later installed.

The two characteristics which any agricultural drainage project must possess for its perfect success are, first, effectiveness, and second, profitableness. If an elaborate plan for drainage improvement, when actually carried out, fails to drain the land sufficiently to secure a satisfactory cultivable condition the project is a failure. In fact, it is even worse than a failure, for not only may it mean an actual financial loss to its owners, but as an example may discourage others from undertaking other meritorious projects. So vital is it to secure adequate drainage that if any constructive work at all is undertaken, it would seem that everyone connected with such work would appreciate its importance. Yet almost innumerable instances can be found where drainage improvements have been planned and constructed on a scale entirely too small to secure efficient results, and where those responsible for carrying out the work should have known in advance that the benefits resulting from their misdirected efforts would not be commensurate with the expenditures incurred.

It is characteristic of almost all artificial drainage improvements that, if a certain amount of work is needed, the actual construction of a part only of the whole work will not produce a correspondingly proportionate benefit; that is, if only one-half of the needed work is carried out much less than one-half of the full benefit will be obtained. It is, perhaps, approximately true that the carrying out of three-fourths of the needed work would yield one-fourth of the total benefit. The last one-fourth of the work produces perhaps three-fourths of the benefit. It is on account of this relation that the original planning of all drainage work on a sufficiently comprehensive and adequate scale is so important.

Naturally those who have had no experience in constructing drainage improvements can have little comprehension of the innumerable difficulties and obstacles that may arise in the construction of extensive work and in its operation after completion; and, too often, when they have the responsible charge of such work, they are prone to refuse to accept the advice of others who have had extended experience. There are still intricate problems and baffling uncertainties, numerous enough, in securing drainage in difficult situations, but there would seem to be no excuse nowadays for undertaking important work in violation of fundamental principles of drainage science well known to every experienced worker in this field of engineering.

It is not alone sufficient, however, that the drainage work as constructed shall secure the desired benefit. The work must be done economically and in such a way as to secure the greatest profit to

the landowner. Several quite different plans for the drainage of a given district might secure equally well the desired improvement. In such a case that plan should be chosen which will prove cheapest in the long run; and to determine the best and cheapest plan is the special province of the engineer. One of the first steps taken in beginning a large drainage project should be to secure the services of a competent and experienced engineer. Such a man is needed to make the necessary surveys and plans for the work; to make inspections and estimates during construction; and, when a pumping plant is a part of the work, to test the completed plant to see that it complies with the specifications and meets the guaranties of capacity and efficiency. He is needed also to advise as to the most economical and efficient operation of the plant after its completion and as to its management, maintenance, and care.

Drainage by means of pumps has been carried on in European countries for the last 100 years and has been rapidly increasing in this country during the last 25 years. Through this extensive experience, including numerous failures, a considerable amount of knowledge is now available on the subject of the proper arrangement and the requisite capacity of pumping plants. It is the object of this bulletin to discuss the various questions arising in connection with the reclamation of agricultural land by means of pumps in order that the conclusions drawn from experience may be available to all landowners, district officers, and drainage engineers who are interested in this kind of drainage.

DRAINAGE PUMPING IN NORTHERN EUROPE.

Draining with the aid of pumps, or what may be termed "lift drainage," is required for large areas of productive agricultural land in Europe. Notable examples of successful work of this character are found in Holland, eastern England, and in Ireland, while large marsh areas in both northern and southern Italy depend upon pumps for adequate drainage. The development of mechanical means of removing water from the land has, in most instances, been forced upon landowners when gravity drainage failed to give sufficient relief, and for that reason the movement was slow, particularly in the early history of such drainage. The pumps which were first used were the well-known scoop wheel and the Archimedean screws, which were driven by windmills.

The Zuidplas polder of Holland, containing 10,363 acres, lies 22 feet below the level of the River Yssel, into which it is drained. In 1825 the basin was drained by dividing it by a canal into two parts and raising the water into the river by two lifts. The first or lower lift was accomplished by 15 windmills driving 8 Archimedean screws and 7 scoop wheels, while for the upper lift there were 15 windmills

driving 10 screws and 5 wheels. These were later supplanted by two pairs of pumping stations, each having scoop wheels and centrifugal pumps, all driven by steam, by which means the drainage of the entire tract is now accomplished.

The great Haarlem Lake of Holland is often referred to as the most remarkable pumping drainage project known. The total area of the tract, which is now surrounded by a canal 37 miles long, is 41,648 acres, 3,011 of which are occupied by roads and main waterways. The work of removing the water in this lake, which was originally 15 feet deep, was completed in 1852, after 39 months of pumping. It is kept drained by three pumping plants of 350 horsepower each, located at opposite sides and at one end of the great basin. The combined capacity of the three plants is nearly 2,000 tons of water per minute raised to a height of approximately 15 feet. The area which was formerly a lake is now traversed by well-improved highways and is occupied by about 20,000 people.

In September, 1913, the Dutch Government authorized the undertaking of a much greater project. It is planned to dike off about 1,000,000 acres of the southerly portion of the Zuider Zee. A little over one-half million acres will be completely reclaimed and made suitable for the production of crops, the remainder will form a reservoir for the discharge of the River Yssel while the tide gates into the untouched portion of the Zee are closed. The work, as planned, will consume 33 years in the construction and will require an appropriation of \$130,000,000. The annual revenue from the cultivation of these lands is estimated at \$28,000,000 and the population it will support at 300,000. Fifteen steam pumping plants with a combined horsepower of 17,000 will lift the water out of the various divisions of the main district.

The drainage of large portions of the fenlands in eastern England was originally accomplished by means of scoop wheels operated by windmills. It was not an uncommon occurrence for the districts to be inundated because of the failure of the pumps to operate when required to remove the water. Losses from this cause became so great that the several plants were gradually equipped with steam power, which rendered the drainage of the land much more certain than under the old system.

W. H. Wheeler, in his *History of the Fens of South Lincolnshire*, states that the entire fens known by that name cover about 363,000 acres, that about 85,000 acres are from 6 to 12 feet below high-water level, and that 124,600 acres of this area are drained by steam power. The pump originally used was the large scoop wheel still operated in many of the plants, but the centrifugal pump is gradually being introduced as being better suited to the conditions now prevailing. The same author, in his book entitled *The Drainage of Fens and*

Low Lands," enumerates 13 distinct districts having areas varying from 800 acres to 35,000 acres which are now drained by steam plants operating either the improved scoop wheel or the more modern centrifugal pump.

From available data it appears that not less than 203,000 acres of lowland in eastern England depend upon pumps for their drainage. The efficiency of these plants has from time to time been greatly increased until it is now estimated that the average cost of pumping in eastern England is 2 cents per acre for each foot the water is raised.

The conditions which are found in Europe are in many respects different from those we are required to meet in this country. The history of drainage by pumping, however, during the last 100 years shows a gratifying and substantial development of mechanical devices and the utilization of power for draining, and establishes beyond question the practicability of this kind of reclamation. The experience and practice of northern Europe are exceedingly valuable to those who contemplate the design and construction of works of this class, a study of which should prevent us from falling into certain errors that have at times been expensive and discouraging to European enterprise in land development.

PAST EXPERIENCE IN THE UNITED STATES.

In this country, among the plantations in the lowlands along the Gulf of Mexico, pumping has been in vogue for a long time, especially for the drainage of lands devoted to the cultivation of sugar cane. Recently the reclamation of the wet lands in southern Louisiana has progressed rapidly and there are now a large number of projects completed and others in the various stages of construction. The total area thus taken in is about 240,000 acres.

Pumping was first introduced in the bottom lands lying along the Illinois River and the adjacent portions of the Mississippi about 25 years ago, but little was accomplished previous to 1900. Since 1905, however, numerous large plants have been constructed. In the spring of 1915, 19 separate plants along the Illinois were in operation, pumping the drainage water from a total area of about 161,000 acres. These plants have a combined capacity of about 6,300 horsepower and represent an investment of about \$500,000. There are under construction three additional plants to provide for the drainage water from about 21,000 acres. With the completion of this work nearly all the available bottom land along the Illinois River will have been reclaimed. For all the improvements constructed in drainage districts as such the expenditure was about \$4,800,000.

Along the Mississippi River in the States of Iowa, Missouri, and Illinois the movement is well started, and it is now evident, from the numerous inquiries for information received from these and many

other States, that there exists at the present time a very active and widespread interest in this whole question. Between Muscatine, Iowa, and St. Louis there are in operation 10 separate plants, which take the drainage water from about 215,000 acres of land. Other plants are under construction or contract on five districts which have a total drainage area of 128,000 acres. The combined horsepower of the plants on the Mississippi is about 7,000. The cost of the district drainage improvements, including the pumping plants, totals a little over \$4,000,000.

The experience of those who undertake projects for pumping drainage water without previous experience in similar work or full and accurate knowledge of what has been accomplished elsewhere shows that invariably they greatly underestimate the magnitude and difficulties of the work contemplated. In this regard their experience is identical with that of those who have been pioneers in other forms of agricultural drainage work. As a consequence the first pumping plants were entirely inadequate in capacity, inefficient in operation, and largely a waste of the money invested in them. In numerous cases they have been added to or entirely replaced by the building of new plants. The officials having in charge the construction of the improvements on the newer districts have profited by the experience of the older districts, and have realized the folly of spending money for inadequate improvements. As a result nearly all of the more recent plants, with their ample and economical machinery, are models of convenient arrangement, permanence, and durability. The decreased cost of operation and the splendid drainage obtained have paid for the increased expenditure many times over.

In the upper Mississippi Valley the various conditions prevailing, such as intensity and distribution of rainfall, length of growing season, and kinds of crops raised, differ widely from those obtaining near the Gulf of Mexico in Louisiana, leading to correspondingly wide variations in recent drainage practice. The former situation will here be taken up in detail, and the planning of districts, the requisite sizes and kinds of machinery, the first cost, and the cost of maintenance will be discussed. The situation in Louisiana is dealt with in a previous publication.¹

DRAINAGE BY PUMPING IN THE UPPER MISSISSIPPI VALLEY.

In Illinois and the adjacent States the bottom lands which have been reclaimed by pumping are in the heart of the corn belt and possess a heavy, rich, black soil, mixed in places with a varying amount of sand. They are adjacent to thickly populated lands, and in some cases lie within a few miles of large towns. This proximity to some of the most fertile and highest priced agricultural lands in

¹ U. S. Dept. Agr., Bul. 71, *The Wet Lands of Southern Louisiana and Their Drainage*.

the United States has led to an earlier activity in drainage reclamation than has existed in most other portions of our country. The results of adequate protection and drainage are shown by figure 1 of Plate IV, a view of part of a tract of reclaimed land on the Illinois River.

SIZE OF PUMPING DISTRICTS.

In order that the building of a levee around a tract of overflowed land and the installation and operation of a pumping plant may be carried out economically at a moderate cost per acre of land reclaimed, it is necessary to have a considerable area included in a single project. Hence, ordinarily the land does not belong to a single owner, but rather to a number of individuals. In order that all the interested landowners may work harmoniously together it is necessary, first, that an incorporated drainage district be formed according to the method provided by the specific laws of the particular State relating to this subject. The officers of the district so formed may then proceed to carry out the successive steps necessary in the inauguration of the construction work.

Pumping districts of as small an area as 3,000 acres may profitably be formed in favorable locations; but, in general, the expense per acre is less as the district is larger up to a certain limit beyond which there is no further advantage from increased size. According to experience, about 10,000 acres of reclaimed land seems to be a very satisfactory size for such a district.

However, the boundaries of a district are determined largely by the natural surface conditions. A district will naturally include all the land on one side of the river between the channel and the bluff and extending up and down the valley from one tributary to the next of any size entering the river on the same side. The tendency in recent years has been to make the districts larger and to extend them beyond the so-called natural boundaries—the tributaries to the river—by diverting these streams around the district or by carrying them by means of levees through the district to the river. The internal drainage channels are carried under these diversion channels by means of concrete inverted siphons or culverts. By this increase in area of the lands organized in one district the expenses per acre of organization and administration during construction and operation are materially reduced. The charge per acre for operation of pumping plant is, in general, much less on the larger district. As the valley ordinarily has the same slope as the high-water line of the adjoining river, the lift of the pumps in forcing the drainage water into the river is very rarely increased by extending the district a greater distance along it. On the other hand, smaller districts are being now reclaimed than formerly was the practice. This is due to the increased demand for land, which makes reclamation profitable

for small, isolated tracts of valley land whose reclamation had been deferred because of the heavy expense attached. The future will see the reclamation of both larger and smaller districts.

LEVEES.

The protective levee begins at the bluff at one end of the district, follows along the bank of the entering tributary to its junction with the river, thence along the river bank to the other tributary, and up that again to the bluff. Thus, ordinarily, the levee extends continuously around three sides of the district. The correct location of the levee to secure a good foundation and to leave sufficient flood-way for the river, and its proper construction of sufficient strength to resist erosion, undermining, and overtopping, are engineering questions of vital importance to the welfare of the district. It was the unfortunate experience of nearly every one of the early levee districts on the Illinois River that, as first constructed, the levees were entirely inadequate in size and strength, with the result that they were broken by floods, their interiors were inundated, and years elapsed before the districts recovered from the injury. With the interior of a district in cultivation the damage from one flooding due to a break in the levee might easily exceed the entire cost of building a levee of ample size to protect the district. This has occurred on a number of the levee districts on both the Illinois and the Mississippi Rivers. The levees on the Warsaw-Quincy District were originally built and later repaired and strengthened at a total cost of about \$500,000. This district was flooded in four different years, and each time the estimated damage was over \$600,000. By spending the proper amount of money originally a saving of at least \$1,500,000 could have been made. The total cost of the levees, including first cost, repairs, and enlargements on the Sny Island District was about \$1,125,000. The estimated damage of five years of flooding between 1876 and 1903 was approximately \$2,700,000. Similar damage has resulted in many levee districts. The older a district becomes, the greater the damage which may result from a break in the levee. In the construction of the levees around new districts the need of an ample margin of safety is now generally admitted, and many of the older districts are enlarging levees which have withstood record high-water stages in the adjoining river. Officials and landowners in levee districts should make certain that the levee is properly designed, located, constructed, and maintained.

LOCATION.

The location of the levee will influence its design, construction, and maintenance. Intelligent location will aid in avoiding poor levee material and bad foundation. Every effort should be made to avoid locating the levee where it will be exposed to strong currents or direct

wave action from the main river channel. Many levee failures have occurred because of poor material, unstable foundation, or erosion. It is usually poor economy and often disastrous to place the levee too near the river channel in order to reclaim a few more acres of land. The ground is quite often lower nearer the river channel, and besides the danger of failure due to erosion, the maintenance expense on levees exposed to wave and current action is always heavy. Government engineers in charge of the Mississippi River work now require that the borrow pits made in levee construction be at least 100 feet from the bank of the river, thus making the minimum distance from the levee to the bank not less than about 150 feet. Consideration must be given to the question of leaving outside the levee a sufficiently wide flood channel. The conclusion reached in any particular case will depend upon the conditions existing upon the opposite banks of the stream, and no definite rules can be stated.

DESIGN.

The height of the levees on districts along the Illinois and Mississippi Rivers varies all the way from zero at their ends against the high ground to 20 feet in places, but they are in general between 8 and 12 feet high. These heights have been fixed with reference to the height of the flood stages in the rivers above the land upon which the levee is located. The top of the levee should be at least 3 feet above highest expected stage.

The dimensions which a levee must have in order that it may be durable and sufficiently strong depend upon the kind of material used, the method of construction, and the nature of the exposure of the levee to the action of waves and currents. A tenacious, clayey soil or gumbo will in general make the best levee. Experience has shown that the least dimensions which a finished and compacted levee should have are a width on top of 6 feet and a slope on each side of 3 horizontal to 1 vertical. Where the location is such that the water remains against the outer side of the levee for only short periods of time, and where the material is exceptionally good, a total slope of 5 to 1 might be divided equally between the two sides. If the material used is very sandy, or if the bank is to be exposed to wave action or strong current, flatter slopes must be used. In this connection it has been the experience on many districts that while coarse, pure sand will erode very readily it will not give trouble from settlement or sliding on the land side during high water. On the other hand, a mixture of fine sand and clay often will become saturated and semi-liquid during prolonged high water and disastrous slides may occur very suddenly. By making the slopes of the levees not steeper than 3 to 1 the all-important maintenance of the levees is much facilitated.

Where good foundation can not be secured for the levee it often becomes necessary to build a sublevee along the land-side toe of the levee slope. This sublevee would usually start at a point on the land-side slope about 8 feet below the grade line of the main levee, run back with a slope of 20 to 1 for about 20 feet, and then down to the surface of the land with a 3 to 1 slope. This type of construction will aid very materially if there is danger of the levee material sliding, it will make available a large quantity of earth for emergency work on the top of the levee, and will also provide a very suitable location for a road.

CONSTRUCTION.

Levees are built with floating dredges equipped with dipper or grab bucket; with land machines usually equipped with drag-line buckets, but sometimes with grab buckets; and with scrapers. Local conditions will usually determine the type of machine to use, but the majority of levees are now constructed with the land machine equipped with a drag-line bucket. If the material is put up wet, there will be very little subsequent settlement, but if the material is dry or if scrapers are used, the original height of the levee must exceed by at least 10 per cent the height required for the permanent levee. In any case the material used to form the levee should all be taken from the river side of the embankment and a clean berm at least 20 feet wide left between the toe of the slope and the nearest point of the borrow pit. The latter must be kept shallow on the side nearest the levee, with a side slope not steeper than the levee slope, so as not to undermine the embankment. In no case should the excavation cross the imaginary line formed by extending the line of the outer slope of the levee down below the surface of the ground. Where a current along the outside slope of the levee is at all likely, transverse strips of earth of a width of 15 or 20 feet should be allowed to remain across the borrow pit at a spacing of about 500 feet. This will reduce the scouring action of river currents and aid the deposition of sediment in the pits. Land machines adapt themselves to this method of excavation, while floating equipment does not. Recently hydraulic dredges have been used very successfully in building levees. This method is especially desirable where the foundation and material at hand are both poor, a combination of conditions which often occurs. The material usually placed into levees by hydraulic dredges is coarse river sand, taken at some convenient point in the river channel. By this method the base of the levee and the surface between the levee and the river bank are left undisturbed and the difficulty of getting a land machine to work across bad foundation is avoided. Experience has shown such levees to be satisfactory. Hydraulic-fill sand levees are also very desirable in crossing the mouths of sloughs which

enter the river channel. Plate I shows hydraulic-fill levees during construction and after completion. The completed levee shown has a top width of about 8 feet, side slopes of 3 to 1, and a height of 12 to 15 feet. Plate II shows a levee constructed by a drag-line excavator.

As in the construction of any other structure, the foundation of a levee is the prime consideration. Unless the material in the foundation is suitable, and unless proper precautions are taken, the levee may fail in spite of the best of construction work on the levee itself. Insufficient care in preparing the foundation for levees has been the most frequent cause of subsequent disaster. Before constructing the levee, the entire area to be occupied by it should be cleared of all vegetation, and all stumps and roots to a depth of 4 feet should be grubbed up. The entire surface should then be plowed, with a large dead furrow in the center. This treatment may suffice if the material in the base is firm and dense, if the levee is only moderately high, and if the water will not stand against the levee for more than a few days at a time. If, however, the material in the base is not of the best, or if the levee is more than 10 feet high, or if the water in the river will remain against the levee for periods longer than 10 days at a time, a muck ditch should always be dug along the center line of the levee. This ditch should be at least 3 feet deep in any case, and always deep enough to cut off any possible seepage. It should be at least 3 feet wide on the bottom and be filled with the best material obtainable, preferably a clayey mixture well compacted. No vegetable matter should be permitted in any of the material used to form the levee. If the subsoil in the borrow pits is clay, this material should be placed in the center of the levee to form a continuous core wall from the muck ditch upward to the top of the levee. The top soil, being thus placed on the slopes of the levee, will facilitate the growth of grass.

MAINTENANCE.

The care of levees subsequent to their completion is an important matter too often neglected. The slopes should be smoothed and as soon as practicable a good growth of grass should be secured. For this purpose bluegrass, Bermuda grass, redtop, timothy, and clover are all used. A good growth of sod will hold the soil in place and prevent erosion. A mowing machine can be used on a 3 to 1 slope, but scarcely on a steeper slope. On a steeper slope, too, beating rains are likely slowly to wash out the soil and thus gradually reduce the height of the cross section. All weeds and brush on a levee should be cut at least twice during the growing season, as they are particularly harmful, loosening and disintegrating the soil by their roots. Sometimes the top of a levee is used as a road, but this practice is not to be commended, for the wagon wheels cut off the

corner of the top and the ruts likely to be formed grow rapidly to such dimensions as seriously to affect the height and efficiency of the levee. The proper place for a road along a levee is on the level ground just inside its inner toe. Burrowing animals of numerous sorts are a constant menace to the integrity of a levee, and they should be assiduously hunted and driven away. Frequently levees are pastured. This has the advantage of keeping down the vegetation, keeping the soil compacted, and driving away burrowing animals. The slight damage to a levee which may result from using it as a pasture is easily observed and repaired and is probably counter-balanced by the good results of the practice. Where the levee is exposed to strong wave action and current erosion, special means must be taken to prevent serious damage during high-water stages. The growth of brush and trees on the edge of the berm next the borrow pits and on the strip of land between the borrow pit and the river should be encouraged. If there is no such natural protection, willows should be planted. In the period before the willows reach sufficient size to be effective some form of artificial protection should be used. Tight board fences are often used for protection against wave wash; a layer of rock, or rock with willow mattress, is often used where the river is cutting the bank and threatening the foundation of the levee. In any case the danger is too serious to be met with halfway measures.

Constant attention and expense, the latter not large, are required for the proper maintenance of a levee. In the long run it will be found infinitely more profitable to incur this small regular expense than to invite disaster during some period of unusually high water by permitting the levee to deteriorate to the danger point. Proper maintenance will be found the best economy in the end.

For a more complete discussion of levee construction, methods of protecting inadequate work in emergencies, and the repair of levees after they have been overtopped and broken, the reader should consult a previous publication.¹

INTERIOR DRAINAGE DITCHES.

An excessive and injurious amount of drainage water may accumulate within the district from three sources: (1) Rainfall, (2) run-off from higher lands draining naturally into the district, and (3) seepage under the levees when the river level is higher than the surface of the land inside the levee. This water must be collected in ditches and led to some suitable point near the levee where the pumps may lift it over the levee and discharge it into the river. The amount of rainfall to be removed by pumping depends upon the amount and distribution of the seasonal precipitation.

¹ U. S. Dept. Agr., Office Expt. Stat. Bul. 158, Separate 9, Report of Drainage Investigations for 1904.

The quantity of run-off from the bluff lands will depend upon their topography and the natural watershed boundaries; the task of disposing of the run-off is often one of the most serious problems to be solved in the planning of a district. The amount of water thus entering the district should be reduced as much as possible by proper location of the levee and by a diversion ditch wherever the latter is feasible. The rate of run-off from the higher lands is likely to be several times as great as that from the bottom lands, so that the diversion of the run-off from a relatively small amount of hill land may greatly reduce the necessary capacities of the internal drainage ditches and pumping plant and diminish the annual operating charges.

Owing to their high velocities the hill streams carry a great amount of silt, and as the slopes of the channels in the bottom lands are very flat the velocity of flow is reduced and the larger percentage of the silt is deposited soon after the water leaves the hills. On many of the districts along the Illinois and the Mississippi Rivers the silting of the interior drainage ditches by waters from hill streams has entailed a heavy expense for its removal. During 1914 a contract was let by the Hillview Levee and Drainage District to remove an estimated total of 90,000 cubic yards of silt from the interior drainage ditches at a unit price of 18 cents per cubic yard. On the Mississippi River the surveys showed that on the newly organized Indian Grave Drainage and Levee District certain natural channels had been silted by hill streams to such an extent that it was considered necessary to construct new artificial channels, although at a very recent date the natural streams were of ample cross section to serve as main drainage channels for the district. It is estimated that because of this silting it will be necessary to excavate several additional miles of channel at a cost of from \$30,000 to \$40,000. It is evident that the damage which the silting of interior channels may cause will justify in most cases a considerable expenditure for protection.

The only district known on either of the above rivers where diversion has been tried on an extensive scale for any considerable length of time is the Coal Creek Levee and Drainage District near Beardstown, Ill. (See fig. 1.) A large diversion ditch and levee were constructed about 10 years ago along the base of the bluff for a distance of about 4 miles, from the point where Coal Creek debouches from the hills to the lower end of the district. The levee is on the lower side of the ditch; that is, on the side toward the district. Not only is the flow of Coal Creek received by the diversion ditch, but several smaller streams also flow into it. This ditch, though sufficiently large at first, became too small by being filled with sediment brought down from the hill during floods, so that the various streams overtopped the levee and flowed into the district. In 1909 another ditch

and levee were completed, but these differ from the previous construction by being so located as to include a settling reservoir opposite the mouth of each stream. These reservoirs receive the sand and sediment brought down from the hills, and thus prevent the ditch from becoming clogged. The reservoirs were planned to be of



FIG. 1.—Map of Coal Creek Levee and Drainage District, Illinois.

such size that they would not become filled with sediment for many years. Two of them are, respectively, 5 and 20 acres in extent, while two are of 6 acres each and three are of 4 acres each. Figure 2 of Plate IV is a view looking west-northwest across Hood Basin, the largest of the reservoirs. Across the basin may be seen a part of the embankment of the original diversion ditch which failed. The

hills in the background show the nature of the country drained by Coal Creek. The last-built ditch and its reservoirs have now been in use for six years and an inspection made in the latter part of 1914 indicated that they would still be effective for a number of years. No other district has installed so complete a system of silting basins in connection with diversion ditches. The Eldred and the Crane Creek Districts on the Illinois River and the Ellsberry and the Des Moines County No. 1 Districts on the Mississippi River have constructed diversions for the hill drainage, though not all of them were able to divert the hill drainage in its entirety. The locations of these districts and the details of their improvements will be found in the summary of all districts given at the end of this bulletin.

In constructing diversion ditches the experience of the Coal Creek District should be kept in mind and ample provision made for the deposition of silt before it reaches the diversion channel proper, otherwise the usefulness of the latter will be of very short duration. Even when silting basins are provided it should be remembered that they will eventually become filled, and they should therefore be so located that other basins can later be constructed to receive the silt from the same stream without incurring needless expense due to the improper location of the first basin. Local conditions will determine the plan to be followed, but the subject merits the most careful study. While in this country work of this nature is just starting, in England and Holland diversion ditches to prevent drainage water from flowing from higher lands onto lower areas, to the great damage of the latter, have been in systematic use for a long time.

If the levees are properly constructed, as heretofore explained, the amount of seepage water passing under them is ordinarily so small as to be negligible, but if the soil or the subsoil of the district be very sandy, or if the levees have been carelessly constructed upon an improper foundation, the seepage may accumulate in sufficient quantity to be troublesome. Ordinarily, if land near the levee is injured by seepage, the difficulty may be corrected by laying a line of tile parallel with the levee and 50 to 100 feet from the toe of the slope.

The determination of the proper size and arrangement of the interior drainage ditches for a pumping district is not fundamentally different from the planning of a gravity ditch system for an ordinary district. The same hydraulic principles apply to the one as to the other, but in some details essential modifications are necessary. Ordinarily river-bottom land has a somewhat uneven surface, varying in elevation by several feet, and lies in long ridges and depressions, which latter bear local names as lakes, sloughs, or creeks. The ridges may be quite sandy, while the lakes contain a heavy black soil. To fit all the land for cultivation the drainage system should be planned to keep the ordinary ground-water level at least 3 feet

below the surface of the ground in the lowest spots that are to be cultivated. This is necessary, not only for the purpose of providing room for the root systems of growing crops, but also as a margin of safety by furnishing a reservoir capacity in the drained soil for the temporary storage of water after an unusually heavy period of rain.

In some localities there are sloughs so low that to drain them would require undue expense. In such a case it is better to reserve these areas for use as reservoirs in connection with the ditch system, with the expectation that they will fill with water during heavy rains and store it until it is gradually removed by the operation of the pumps. This tends to reduce the maximum capacity required of the pumping plant of the district concerned. Some districts on the Mississippi River have as much as 7 per cent of their total area occupied by such storage basins, but other districts have none at all, and such storage areas do not seem to be essential in regions where the natural topography of the ground surface is not favorable for their use.

The main ditch and its branches should traverse the lowest areas in the district, following the land subdivisional lines where practicable. This will secure surface drainage in the lowest areas, where it is most needed, and also prove cheapest because the amount of excavation will be a minimum. Cutting ditches through the ridges should be avoided as much as possible, especially where these are sandy, on account of the great difficulty of making and maintaining a ditch in sandy soil owing to the trouble caused by the caving banks. At times the previously existing natural drainage channels, when suitably cleaned, may be made to form a considerable part of the ditch system.

Sometimes the district as a whole has very little surface slope, and it becomes necessary to dig the main canal deeper as it nears the pumping plant in order to keep the water surface parallel with the ditch bottom. Having determined the point above which the water should not rise in the portion of the district remote from the pumping plant, and knowing the capacity of the plant, the slope necessary in a ditch of given size to bring the water to the pumping plant fast enough to keep it operating continuously can be calculated. A small ditch will deliver the water at a lower point at the pumping plant than will a larger one, as the slope will have to be greater for the same discharge. This will mean increased power for driving the pumps. The size of ditch and of pumping plant should be mutually adjusted to secure a minimum operating cost, including interest on investment, depreciation, and expense of operation for the pumping plant, and interest and depreciation on the ditch. The foregoing is based on the fact that the capacity of pumping plant used in this section is nearly uniform. At times of heavy rainfall the ditch will be filled with water and for a short time will deliver more water than

is necessary to keep the plant operating; at other times the low-water flow of the ditch will be sufficient to warrant the plant operating only a small portion of the time. This feature will be discussed in more detail under the heading, "Necessary capacity of pumping machinery."

The greatest amount of sediment is likely to be washed into the main ditches during a heavy storm when the ditches are bank full. It should be noticed that at such a time there is an important difference between the condition of these ditches and that existing in main ditches of gravity drainage systems. In the latter, when more than normally full, the velocity is a maximum, and hence there is the least possible tendency toward the deposition of sediment in the ditches. But in a pumping district, on the contrary, when the main ditches are unusually full, the velocity will be low, and hence sediment may be easily deposited. As a rule, the velocity in these ditches will always be so low that they are not self-cleaning. On this account, as well as on account of the drawing down of the level in the ditches by the pumps, such ditches should be of unusually generous dimensions. The engineer will wisely give particular attention to the designing of the ditches to insure ample depth and breadth to provide the requisite capacity. In general, it is probable that the main ditches should be dug from 8 to 10 feet deep. Figure 1 of Plate V is a view of the main ditch, Coal Creek Levee and Drainage District, Illinois, which was constructed in 1909 with a dipper dredge having side spuds. The view was taken before the ditch was completed at the lower end. The water level as shown is about 4 feet below the ground surface and about 4 feet above the normal level after the ditch was completed. Figure 2 of Plate V is a view looking up Branch A of east lateral, from near the outlet of tile drain No. 7. An inspection of these ditches at the end of 1914 showed them to be in very good condition and remarkably free from deposits of silt. This very desirable condition of the ditches is largely due to the complete diversion of silt-bearing waters from the hills. Other districts already in operation would do well to investigate the advisability of treating their hill drainage in a similar manner.

Experience shows that to put bottom land into perfect agricultural condition considerable tile drainage is necessary. This has been demonstrated on all the districts along the Illinois and Mississippi Rivers, and landowners who have already been put to considerable expense for the main drainage of the district can not afford to have their land in any but the most fertile condition; it is, therefore, money exceptionally well invested to go to the additional expense involved in the necessary tiling. Tiling in such lands should be done with the same careful attention to the slope and to the nature of the soil and subsoil as is necessary in getting the desired

results in any other case of underdrainage, as the problems to be encountered are similar. A very large percentage of the bottom land reclaimed by means of pumps is now very completely tile drained. Nearly all the small surface ditches have been replaced with tile. On some of the districts even the larger lateral ditches have been replaced with large tile, and the plans for the drainage of new districts now call for tile drains where formerly open ditches would undoubtedly have been recommended. On the Langelier District, near Havana, Ill., practically all the open ditches, both large and small, have been replaced with tile drains, until only about 2,000 feet of open ditch now remain. Thus far the system has been satisfactory, although it has not yet experienced an extremely wet season. Future experience on this district will furnish valuable data for guidance in the design of systems which are to include tile drains. The replacing of open ditches with tile drains will reduce the maintenance charges on the interior drainage channels and will effect a saving in land. The question of laying tile drains in the bottoms of broad, shallow depressions to be used as floodways for storm run-off deserves careful consideration in planning drainage improvements of this character. By laying tile drains a few feet below the bottoms of open ditches which are no longer deep enough to give a sufficient depth of drainage the combination of ditch and underdrainage may be very cheaply attained.

On account of the surface erosion and consequent sedimentation in the main ditches small open surface field ditches or laterals emptying into the main ditches are highly objectionable unless for some distance back from the junction they are dug as deep as the bottom of the main ditch. The difficulty could be avoided by the use of some sort of permanent and stable masonry inlet; otherwise small ditches should be replaced by tile.

GRAVITY SLUICWAYS.

In the case of districts where the river falls low enough during the latter part of the summer to afford an outlet for gravity drainage, sluiceways, so arranged that they may be opened when desired, should be built under the levee near the pumping plant. The sluices should be composed of one or more parallel pipes laid nearly level and provided with suitable valves. The length of the pipes will naturally be 100 feet or more. Metal, concrete, or vitrified sewer pipe may be used in their construction. Both ends should be protected with strong concrete bulkheads, and cut-off walls should be placed around the pipes at intervals along their length to prevent seepage along their exterior surface. Cracking and failure of these end bulkheads, one of the commonest accidents in drainage districts, show that they must be made with special care, amply deep, and of

liberal dimensions. If the outer end of the sluiceway is not below low-water line of the river, the bottom of the channel through which the water will flow beyond the end of the pipe should be protected from washing out by riprap, paving, or a concrete floor carried to a safe distance. Where feasible, this protection should extend below low-water line.

The sluiceway should be sufficient in size to discharge in 24 hours such an amount of water as would cover the whole drainage area one-fourth inch deep. In making this calculation the velocity of the water through the sluiceway should not be assumed to be greater than 5 feet per second. The sluiceway openings should be low enough so that their highest point will be at about the line at which it is desired to maintain the water level within the district. Their interior surfaces should be as smooth as possible in order to reduce the friction which retards the flowing water. If the entrance to the pipes is made well rounded, their maximum discharging capacity will be considerably increased. Automatic outward-opening flap valves may be put on the outer end of the pipes, but in important cases there should be also a place where the pipe may be closed by stop planks or by a gate valve if the automatic valve should get out of order.¹ On large sluices hand-operated gates of standard construction are much preferable to the automatic type, as they are positive in their action and not likely to get out of order. An excellent sluice with four compartments and four gates is shown in figure 1 of Plate III.

DESIGN OF PUMPING PLANT.

NECESSARY CAPACITY OF PUMPING MACHINERY.

Before discussing in detail the conditions determining the size needed for a pumping plant it will be illuminating to describe the general method of operation of such a plant in the latitude of Illinois. In the late summer and fall, since the precipitation is slight and is more than balanced by evaporation, the pumps are not run. During the winter storms are more frequent and evaporation is small, so that gradually the ground becomes completely saturated and the ditches full. Some districts pump occasionally throughout the whole winter; others start the pumps at some date in the spring and operate them continuously night and day for several days to remove the large accumulation of water stored up during the winter months. Gradually the water level in the ditches is lowered, and when the desired minimum is reached the machinery is stopped during the night. The water will rise in the ditches perhaps 2 or 3 feet during the night. When the pumps start up in the morning the water level at the pumping plant quickly drops a foot or more and then more slowly for the rest of the day. At points some distance away the effect of

¹ U. S. Dept. Agr., Office Expt. Stas. Bul. 158, Separate 9, Report of Drainage Investigations for 1904.

starting the pump is less quickly seen in the morning, but the lowering of the water is gradual throughout the day. After a few days of such operation the supply of water diminishes and the pumps are not run the whole day.

Later, since it is troublesome to start up a big plant for only a few hours of operation, the speed of the engine and pump is reduced to diminish its discharge, or, if there is more than one pump in the plant, only one may be run. At last, days are skipped and pumping ceases entirely. After every rain of any importance, the pumps are started and a similar cycle of operations transpires, extending over a longer or shorter period, according to the amount of water to be removed. In some districts pumping for the season ends in June, and drainage is by gravity for the remainder of the summer. In others no gravity drainage is available, and the pumps must be run later in the season. Thus it is clear that, though the pumps must constantly be in readiness for use, their operation is very intermittent. The total time of running in a whole year never exceeds 60 to 90 days of 24 hours each. In some seasons it is not more than 15 to 20 such days.

The size of pumping plant required for any particular district depends upon a variety of conditions, among which are the size and slope of the drainage district and of any other area from which drainage water is received; the amount of storage capacity available in ditches and reservoirs; the system of interior drains used and the method of construction adopted for the levee; the nature of the soil and subsoil; the method of operation of the pumping plant; the kind of crops raised and the degree of drainage required; and the amount and distribution of the rainfall throughout the year.

In the vicinity of Illinois the weight to be given to some of these factors is very small, and in the present state of our knowledge no definite allowance can be made for them. Yet, notwithstanding our ignorance concerning some of them, it may be profitable to discuss briefly the nature of the effect of each. This is a field in which much careful study is still needed and must be carried out to secure the complete knowledge necessary for the most satisfactory design and management of the pumping machinery of drainage districts.

Along the Illinois and upper Mississippi Rivers the majority of pumping plants already installed have been planned to have a maximum pumping capacity sufficient to remove in 24 hours one-fourth inch in depth of water over the entire district. This is equivalent to 6.74 cubic feet per second per square mile of drainage area, or 0.0105 cubic feet per second per acre.

It is doubtful whether any change should be made in the one-quarter inch coefficient solely on account of change in the size of the district; however, where some portions of the district are materially higher than others, the coefficient might be increased to pre-

vent danger to the lower portions from the run-off from the higher areas. Where drainage from higher land flows into the district a larger run-off coefficient must be used for the higher area. The proper amount depends upon the nature of the country. For rolling pasture land free from undergrowth, or for cultivated corn land, probably an increase of 50 per cent in the coefficient, or a total of three-eighths inch, for such upland areas is none too great. Where feasible, the drainage from such higher areas should be diverted around the district, as previously explained, instead of being brought to the pumping plant.

With a considerable reservoir storage area within the district, the size of the pumping plant may be materially reduced. If the storage area equals 5 per cent of the total area, a 2-inch rainfall, all running into the reservoir, would raise its level only 40 inches. Therefore, if a rise of 3 feet in the reservoir can be permitted it would seem that the capacity of the pumping plant could certainly be reduced by one-third and possibly by one-half of what would otherwise be required.

If tile drainage at a depth of 3 feet or more is extensively used, the demand upon the pumping plant will be somewhat reduced, for the tiled land will act like a reservoir in storing a large amount of water and will deliver it only slowly to the ditches. On the other hand, an extensive system of shallow open field ditches will deliver the rainfall rapidly and may thus damage any especially low areas unless the capacity of the pumping plant is increased. If the levees have been properly constructed, the amount of seepage through them can never be sufficient to affect the pumping plant. Cases have been known, however, of levees so poorly built that the quantity of water coming through them was sufficient not only to endanger the stability and safety of the levees themselves, but also to increase appreciably the amount of water to be pumped.

If the soil is very stiff and tenacious the surface run-off after a heavy summer shower will be greater than from a porous open soil. During a time of flood in the river, a sandy subsoil may develop springs and boils, not only in the bottoms of the ditches, but sometimes even in the fields. The quantity of water that may be received in this way is very uncertain, but it is not probable that it is often sufficient in amount to affect the pumping plant.

A pumping plant that is designed to operate night and day may, of course, be smaller than one intended to operate only in the daytime. Practically all plants are expected to run nights occasionally, when needed. Pumping plants are operated chiefly during the months from March to June. One of the times of longest continuous operation during the whole year is always at the beginning of pumping in the spring, because if there has been no pumping during the

fall and winter the rains and snows will have completely saturated the ground and filled the ditches. Hence, those districts which have had the longest experience in pumping are unanimously of the opinion that even though at that time there is no danger of immediate damage to crops, still it is best to pump occasionally during the winter so as to maintain the ground water constantly at a low level, and thus secure the great advantage of early drying of the soil in the spring and the opportunity for early cultivation and planting. Moreover, the lower the normal ground-water level is kept below the surface, the less will be the flooding effect of a severe storm.

It should be clear from the foregoing discussion that a district which gives especial care and attention to its pumping, running throughout the winter as needed and frequently during the growing season, so as to maintain a minimum ground-water level while there is any danger from the occurrence of heavy and sudden rains, will require a smaller pumping plant than would otherwise be needed.

From a surface covered with a growing hay or grain crop the run-off is less rapid than from land in corn. For corn and hay the ground water must be kept at a lower level than is necessary for grain. Corn is considered the most profitable crop in the region under consideration, and where the soil can be kept sufficiently dry it is raised as frequently as is consistent with a proper crop rotation necessary for maintaining the fertility of the soil. Much land can be observed, however, which is not sufficiently drained for the most successful raising of corn and which therefore is devoted to wheat and oats instead.

The amount and distribution of the rainfall are the chief factors determining the size of pumping plant required in a given location, and we shall proceed to a detailed discussion of all the evidence that it has been possible to gather bearing upon this point. From a consideration of all the data collected to date, the conclusion seems justified that the run-off coefficient of 0.3 inch in depth over the whole drainage district in 24 hours is the correct one to use in designing pumping plants on the Illinois and upper Mississippi Rivers. Direct observations on numerous plants in actual operation for a series of years will be needed to settle the question finally.

In the region just referred to, though some pumping on an inadequate scale has been carried on for about 15 years, all the older districts had until comparatively recently experienced trouble with their ditches and levees which prevented their pumping experience from furnishing conclusive data; from no plant has it been possible to obtain definite records going back more than a few years. Now, though there are more than 20 large plants in operating condition, it is surprising to learn that the majority of these still neglect to keep even the simplest, most fundamental records, such as would deter-

mine whether the plant is operating economically or wastefully—records which would be of great value to the district immediately concerned as well as to others.

As indirect evidence it may be stated that for many years in central Illinois the one-fourth-inch coefficient has been used in designing ditches for the drainage by gravity of flat lands and has been found adequate and satisfactory. For a much longer time in Holland and in the fens of England the coefficient of one-fourth inch or a little more has been the basis used in the designing of pumping plants. Although their total annual rainfall is about the same as in Illinois, their climate is otherwise quite different. In England and Holland there are many more rainy days, so that the rainfall is much more evenly distributed than in this country. In these countries, too, there is much less sunshine and hot weather in summer, and therefore less rapid evaporation. On the other hand, they do not have such violent and excessive rains falling during brief periods as we have.

Valuable data were obtained from the Coal Creek, Pekin-La Marsh, and East Peoria Districts on the Illinois River and from the Louisa-Des Moines District on the Mississippi River. While the records at the plants were carefully kept, unfortunately the periods covered by the most accurate portions of the records do not include any very heavy precipitation. The data obtained from each plant will be discussed in the order the plants are mentioned.

The Coal Creek Levee and Drainage District, near Beardstown, Ill., has been securing drainage by pumping since about 1898, though entire success had not been attained previous to 1909. Up until the end of 1913 the equipment of this plant was as follows: One 24-inch centrifugal pump with a nominal rated capacity of 33.5 cubic feet per second; and two 15-inch pumps, each rated at 15.5 cubic feet per second, or a total capacity of 64.5 cubic feet per second. Since the area of the watershed of the district is 7,425 acres, this would make the approximate capacity of the plant 0.21 inch in depth in 24 hours.

Since July, 1909, accurate and detailed daily records of the operation of this plant have been kept by the owners. With the knowledge gained from these records of the stages of the water in the ditches, the hours of pumping, the rainfall, and the capacities of the ditches at the various ditch stages, the capacity of the plant as operated was estimated. It was found to be a little over 0.14 inch per 24 hours. The rainfall is measured at the pumping station by means of a rain gauge of the Weather Bureau pattern. Between July 1, 1909, and May, 1910, two very heavy periods of precipitation occurred. On July 7, 8, and 9, 1909, the total rainfall was 2.8 inches, necessitating that all the pumps be run continuously for 57 hours, after which one of the smaller pumps was stopped and the other two were operated

for 12 hours. The approximate run-off would be estimated for the first three days of pumping as a total of 0.38 inch. May, 1910, was a particularly wet month at this station; the total precipitation was 5.8 inches, though there were no single remarkably heavy showers. On the first two days of the month 1.4 inches fell; on the 7th, 1.4 inches; on the 11th, 1.2 inches, and from the 15th to the 17th 0.8 inch. To meet this steady wet period all three pumps were run continuously for 72 hours from the 13th to the 15th, and again for 42 hours on the 18th and 19th. The estimated amount pumped in each period would be 0.42 inch for the first and 0.35 inch for the second. During this month the plant was operated at full capacity for 70 per cent of the time, removing a total estimated depth of 3.04 inches of water from the district. In the period from July 1, 1909, to July 1, 1910, the estimated total amount pumped was 20 inches.

During the latter part of 1913 the above-described plant was replaced with a new one, equipped with three 20-inch centrifugal pumps having a combined capacity of 87.5 cubic feet per second, or a depth of 0.28 inch on the entire district per 24 hours. After installation these pumps were carefully rated at the various heads and accurate records were kept for the year 1914. The year was unusually dry, and only one storm period of any consequence occurred during the entire year. The rainfall and amount pumped for this storm period are shown in Table 1.

TABLE 1.—*Daily rainfall and run-off, Coal Creek Levee and Drainage District, March 25–April 11, 1914.*

Day.	Rainfall.	Run-off.	Day.	Rainfall.	Run-off.	Day.	Rainfall.	Run-off.
	<i>Inch.</i>	<i>Inch.</i>		<i>Inch.</i>	<i>Inch.</i>		<i>Inches.</i>	<i>Inches.</i>
Mar. 25.....	0.25	0.06	Apr. 1.....	0.32	0.10	Apr. 8.....	0.00	0.15
26.....	.00	.05	2.....	.00	.12	9.....	.00	.12
27.....	.75	.07	3.....	.00	.12	10.....	.00	.11
28.....	.25	.10	4.....	.00	.12	11.....	.00	.10
29.....	1.00	.24	5.....	.00	.10			
30.....	.00	.14	6.....	.00	.10	Total..	3.57	2.10
31.....	.00	.16	7.....	1.00	.14			

Data for the above district for the year 1914 are shown in Table 2.

TABLE 2.—*Monthly rainfall and run-off, Coal Creek Levee and Drainage District, 1914.*

	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Total.
	<i>In.</i>	<i>In.</i>	<i>In.</i>	<i>In.</i>	<i>In.</i>	<i>In.</i>	<i>In.</i>	<i>In.</i>	<i>In.</i>	<i>In.</i>	<i>In.</i>	<i>In.</i>	<i>In.</i>
Rainfall.....	3.11	2.50	2.25	1.70	1.88	2.00	2.01	2.41	3.88	1.89	0.00	1.87	25.50
Run-off.....	.62	.78	2.60	2.65	1.10	.76	.40	.12	.48	.47	.49	.52	10.99

During the history of its pumping, extending over about 25 years, the Pekin-La Marsh Levee and Drainage District, near Pekin, Ill., has had several different pumping plants, but at the end of 1914 it had the following equipment: One 26-inch centrifugal pump with an

approximate capacity of 30 cubic feet per second and one 12-inch centrifugal pump with a capacity of 8.5 cubic feet per second. The combined capacity in depth per 24 hours is now 0.28 inch over a watershed of 3,200 acres. Previous to January, 1912, only the 26-inch pump had been installed. Up to that time only a rough daily memorandum had been kept of the operation of the plant. However, some estimates were possible for pumping done during that time. In 1909 this plant started on March 10 and operated intermittently as required until July 25, during which time the district was drained satisfactorily. The total time of operation was forty-five and seven-tenths 24-hour days, making the total depth of water removed 10 inches. During this period the most severe test of the capacity of the plant was 4 days of steady operation, July 7-10, followed by 7 hours on July 11, or a continuous run of 103 hours. This was caused by a heavy rain on July 5, 6, and 7, totaling 4.1 inches. The amount pumped was approximately a depth of 0.96 inch from the whole district. In October, 1909, the pump drive was changed from gas engine to electricity; from that time until June 20, 1910, a total of 1,365 hours were run, equivalent to 56.9 days. The total depth pumped during this period was approximately 12.7 inches. During this period the plant was never run more than 12 hours in one day, and very seldom as much as this. As will be shown later, the year 1909, although not an extreme one, was rather wetter than the average, while 1910 was remarkably dry.

After January, 1912, an accurate daily record of the pumping was kept, and from these records the daily amount pumped has been calculated. While the capacity given for the large pump is only approximately correct, most of the pumping was done with the small pump, which had been carefully rated. In Table 3 is given a statement of the daily rainfall and amounts pumped for the largest storm periods in 1912 and 1913. The year 1914 was unusually dry and no storm of consequence occurred during the entire year.

TABLE 3.—*Daily rainfall and run-off, Pekin-La Marsh Levee and Drainage District, 1912 and 1913.*

Day.	Rainfall.	Run-off.	Day.	Rainfall.	Run-off.	Day.	Rainfall.	Run-off.
	<i>Inches.</i>	<i>Inches.</i>		<i>Inches.</i>	<i>Inches.</i>		<i>Inches.</i>	<i>Inches.</i>
1912.			1912.			1913.		
Apr. 26.....	0.54	0.05	June 10.....	0.00	0.03	Mar. 19.....	0.00	0.06
27.....	.00	.08	11.....	.00	.03	20.....	.15	.06
28.....	1.08	.12	12.....	.22	.03	21.....	1.22	.10
29.....	.42	.14	13.....	.14	.03	22.....	.00	.11
30.....	.00	.14	14.....	.05	.02	23.....	.98	.12
May 1.....	.22	.13	15.....	2.10	.03	24.....	.25	.13
2.....	.74	.15	16.....	.03	.13	25.....	.08	.18
3.....	.00	.23	17.....	.00	.14	26.....	.00	.17
4.....	.40	.16	18.....	.00	.08	27.....	.00	.10
5.....	.40	.13	19.....	.37	.05	28.....	.00	.10
6.....	.00	.12	20.....	.20	.04			
7.....	.00	.09	21.....	.00	.06			
			22.....	.00	.04			
			23.....	.00	.03			
Total..	3.40	1.54	Total..	3.11	.74	Total..	2.68	1.13

It will be noted that the storms occurring in the early spring, when the ground is wet and the evaporation is small, have a much larger percentage of run-off than those occurring in summer. The monthly rainfall and run-off for the above district for the years 1912, 1913, and 1914 are given in Table 4.

TABLE 4.—*Monthly rainfall and run-off, Pekin-La Marsh Levee and Drainage District.*

Month.	1912		1913		1914	
	Rainfall.	Run-off.	Rainfall.	Run-off.	Rainfall.	Run-off.
	<i>Inches.</i>	<i>Inches.</i>	<i>Inches.</i>	<i>Inches.</i>	<i>Inches.</i>	<i>Inches.</i>
January.....	0.00	0.71	1.94	1.04	1.61	0.30
February.....	1.17	.58	2.48	1.18	1.61	.36
March.....	1.68	1.71	3.07	2.85	1.01	1.34
April.....	5.50	2.61	2.86	4.18	2.03	1.32
May.....	4.40	2.61	1.82	1.19	1.90	.83
June.....	4.42	1.24	1.59	.65	1.56	.17
July.....	4.07	.79	1.27	.19	1.44	.02
August.....	2.16	.29	2.74	.00	1.95	.00
September.....	4.40	.27	2.30	.00	5.09	.18
October.....	4.09	.68	2.52	.10	2.10	.21
November.....	1.76	1.28	2.25	.17	.14	.09
December.....	.81	.64	1.21	.26	.41	.06
Total.....	34.46	13.41	26.05	11.81	20.85	4.88

¹ Large run-off due to flow of water through pump from river during high stage.

The East Peoria Levee and Drainage District, on the Illinois River opposite Peoria, Ill., has been pumping since 1911. The plant is equipped with one 15-inch and one 18-inch centrifugal pump. The combined capacity of the pumps is 33.5 cubic feet per second, or a depth of 0.51 inch from the entire watershed of 1,550 acres per 24 hours. Accurate records were obtainable only for the period from September 15, 1913, to September 15, 1914. The weather was very dry and no period of pumping occurred which taxed the pumping plant seriously. The monthly totals of rainfall and run-off are given in Table 5.

TABLE 5.—*Monthly rainfall and run-off, East Peoria Levee and Drainage District.*

	1913.				1914.									Total.
	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	
Rainfall.....	<i>In.</i> 2.38	<i>In.</i> 2.81	<i>In.</i> 2.77	<i>In.</i> 0.73	<i>In.</i> 0.21	<i>In.</i> 1.36	<i>In.</i> 1.60	<i>In.</i> 2.10	<i>In.</i> 2.29	<i>In.</i> 1.95	<i>In.</i> 0.85	<i>In.</i> 2.40	<i>In.</i> 3.90	<i>In.</i> 25.35
Run-off.....	.04	.19	.33	.38	.65	.60	1.06	1.34	1.10	.64	.35	.19	.13	7.00

The largest amount pumped on any one day during the above period was a depth of 0.1 inch on April 7, the first day after a rain of 0.95 inch. The data from this district for 1914 are of no value in the general determination of necessary capacity, but they will be used later in connection with the cost of pumping.

The Louisa-Des Moines Drainage District No. 4, about 20 miles north of Burlington, Iowa, on the Mississippi River, has been pumping since 1909. This district has a watershed area of 16,000 acres

and a pumping plant equipped with two 50-inch pumps having a combined capacity of 225 cubic feet per second, or a depth of 0.33 inch on the entire watershed per 24 hours. Accurate daily records were available for the years 1912 and 1913. The elevation of the land in this district with reference to the usual stages in the Mississippi River is such that for several months in each year gravity drainage is possible through sluice gates. The gates are usually open during the summer, when the storms of the greatest intensity and amount are likely to occur. Under the conditions that usually prevail the time of greatest pumping is during the spring months. The Mississippi and Iowa Rivers, which bound the district on two sides, are usually high at that time, while seepage is at the maximum and evaporation is near the minimum. When pumping was started in March, 1912, there was considerable snow and ice in the district; the rivers rose very nearly to the top of the levees, causing heavy seepage. The rainfall was about normal. Table 6 shows the daily rainfall and run-off for March and April, 1912; it is unlikely that the run-off from this district will much exceed these figures at any time.

TABLE 6.—*Daily rainfall and run-off, Louisa-Des Moines Drainage District No. 4, 1912.*

Day.	Rainfall.	Run-off.	Day.	Rainfall.	Runoff.	Day.	Rainfall.	Run-off.
	<i>Inches.</i>	<i>Inches.</i>		<i>Inches.</i>	<i>Inches.</i>		<i>Inches.</i>	<i>Inches.</i>
Mar. 26.....	0.84	0.18	Apr. 13.....		0.26	May 1.....	1.86	0.16
27.....		.21	14.....		.25	2.....		.16
28.....		.21	15.....		.25	3.....		.17
29.....		.21	16.....		.24	4.....		.18
30.....		.23	17.....	1.93	.19	5.....		.16
31.....		.23	18.....		.24	6.....		.17
Apr. 1.....		.22	19.....		.26	7.....		.15
2.....		.21	20.....		.17	8.....		.15
3.....		.21	21.....		.19	9.....		.15
4.....		.22	22.....		.25	10.....		.13
5.....		.22	23.....		.25	11.....		.13
6.....	.20	.22	24.....		.18	12.....	.27	.12
7.....		.23	25.....		.17	13.....		.13
8.....		.23	26.....		.17	14.....		.13
9.....		.24	27.....		.18	15.....		.00
10.....		.24	28.....		.17	16.....	.46	.12
11.....		.24	29.....		.17	17.....		.13
12.....	.60	.25	30.....		.16	18.....		.11

The plant was not operated an entire day, i. e., 24 consecutive hours, during this time. The object was not to remove all the water possible in one day, but to hold the stage of water in the internal drainage channels below the danger point. If the plant had been operated at full capacity for several entire days, it would have meant the skipping of a day to allow sufficient water to collect for pumping. The mean lift would also have been increased. In this case, contrary to the usual condition on pumping districts, the amount pumped each day must very closely approximate the amount of water that actually ran into the main drainage channels on that day. A study of the stage of water in the main ditch bears out this conclusion. During the pumping season of 1913 neither heavy precipitation nor high river stages occurred and the amount pumped was never more than 0.16 inch in any one day. In Table 7 are given the monthly totals of rainfall and amounts pumped.

TABLE 7.—*Monthly rainfall and run-off, Louisa-Des Moines Drainage District No. 4.*

Month.	1912		1913		Month.	1912		1913	
	Rain-fall.	Run-off.	Rain-fall.	Run-off.		Rain-fall.	Run-off.	Rain-fall.	Run-off.
	<i>Inches.</i>	<i>Inches.</i>	<i>Inches.</i>	<i>Inches.</i>		<i>Inches.</i>	<i>Inches.</i>	<i>Inches.</i>	<i>Inches.</i>
January.....	0.59	0.00	1.55	(¹)	August.....	1.99	0.56	3.29	(¹)
February.....	1.24	.00	2.06	(¹)	September.....	1.86	.67	1.92	(¹)
March.....	2.32	1.27	3.03	2.01	October.....	5.10	(¹)	2.92	(¹)
April.....	2.73	6.48	2.55	4.05	November.....	.99	(¹)	.97	(¹)
May.....	3.49	3.71	5.35	2.58	December.....	1.19	(¹)	.61	(¹)
June.....	1.19	2.07	3.91	2.53					
July.....	2.98	.40	.00	.95	Total.....	25.67	15.16	28.16	12.12

¹ Drainage obtained by use of sluice gates.

Tables 8, 9, and 10 show the monthly and yearly rainfall at Muscatine, Peoria, and St. Louis. These are chosen, as they are located at the corners of a triangle which includes nearly all the area in which pumping is required.

TABLE 8.—*Monthly precipitation, in inches, Muscatine, Iowa.*

Year.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
1846....	2.80	4.50	2.10	5.40	3.40	4.20	1.30	0.50	5.50	1.30	1.80	1.75	34.55
1847....	.79	1.11	2.94	3.30	3.50	4.60	1.20	3.30	2.10	1.21	3.45	1.00	28.50
1848....	1.20	1.61	2.31	.70	3.40	2.50	5.70	9.10	3.00	4.30	1.85	3.95	39.62
1849....	3.15	1.03	2.51	4.70	4.70	12.20	1.40	12.20	5.00	4.80	6.60	.87	59.16
1850....	4.62	.80	2.08	3.32	3.70	3.50	5.00	13.00	3.90	2.70	3.59	2.87	49.08
1851....	1.55	5.34	3.03	3.60	12.60	14.30	8.60	14.00	3.50	1.40	3.63	2.95	74.50
1852....	2.52	1.00	8.60	5.30	6.50	2.20	3.70	2.80	8.30	7.60	5.76	5.11	59.39
1853....	.40	.90	11.80	4.60	6.40	6.60	1.70	6.20	.20	4.90	.32	44.92	
1854....	.40	1.80	1.23	1.76	6.21	.66	2.22	3.33	1.13	4.22	.19	.51	23.66
1855....	3.25	.71	1.87	2.55	1.94	4.75	2.35	3.51	1.84	2.81	2.23	3.32	51.13
1856....	1.22	5.54	.61	3.44	4.39	2.68	2.74	1.36	2.45	5.21	4.35	7.95	41.94
1857....	.61	5.80	3.34	1.90	2.75	.90	4.67	6.60	1.88	1.95	2.92	1.53	34.85
1858....	1.60	3.80	2.20	5.87	8.40	6.67	7.30	4.12	6.10	4.95	4.54	2.90	58.45
1859....	.44	3.89	5.01	3.70	7.49	5.82	2.93	1.70	1.80	.85	1.33	1.00	35.96
1860....	1.17	.43	.55	1.67	1.42	3.66	4.03	2.30	2.76	1.00	2.09	4.02	25.10
1861....	1.50	2.87	4.50	3.93	3.06	1.72	2.65	2.80	9.30	7.20	2.60	2.10	44.23
1862....	4.00	2.50	9.20	7.00	2.65	6.74	3.45	7.25	4.50	2.85	1.32	1.70	53.16
1863....	1.70	1.50	2.00	1.52	1.89	.91	.25	4.15	2.41	3.54	1.44	5.52	26.83
1864....	1.05	.25	2.59	3.43	3.39	5.75	3.25	2.31	3.20	3.11	2.59	1.85	32.77
1865....	.46	2.90	2.76	6.02	1.05	3.69	4.50	4.25	4.23	3.53	.20	.62	34.21
1866....	3.38	.58	1.94	3.91	1.18	2.82	5.18	3.36	4.71	1.94	1.01	2.85	32.86
1867....	.75	3.62	1.93	2.34	5.77	4.70	3.24	1.65	3.44	1.00	2.85	.95	32.24
1868....	.30	.95	5.55	7.43	7.07	2.50	4.59	2.85	5.18	.94	2.71	.84	40.91
1869....	1.62	1.63	1.53	2.64	4.47	9.15	8.55	5.35	1.95	1.59	2.47	2.41	43.30
1870....	2.04	.18	3.37	.38	1.86	.93	1.05	4.46	4.59	3.95	.87	.93	24.61
1871....	2.15	2.09	1.88	1.95	1.93	6.71	3.28	6.12	1.07	3.73	2.30	2.90	36.11
1872....	.06	1.30	2.55	3.92	7.57	5.17	2.97	5.84	4.15	.84	1.30	.74	35.41
1873....	8.49	.35	1.90	1.45	4.31	1.91	2.61	-----	1.30	1.44	1.18	3.49	28.43
1874....	4.72	2.88	2.39	2.93	1.51	3.70	2.26	3.54	6.58	.90	2.49	.88	34.78
1875....	.65	1.50	1.99	.90	2.65	4.97	6.72	2.56	9.38	1.27	.63	4.37	37.59
1876....	3.23	2.85	3.54	4.00	7.38	4.45	9.15	5.72	6.53	1.84	3.48	1.40	53.57
1877....	1.58	2.00	4.28	3.57	2.25	7.44	4.82	4.49	1.25	6.03	3.06	3.01	43.78
1878....	.40	1.56	2.87	2.36	7.49	4.09	3.57	7.43	2.81	4.35	.77	1.60	39.30
1879....	1.20	1.07	2.18	1.81	4.54	3.78	3.40	4.56	2.37	2.85	.45	1.42	33.83
1880....	3.02	1.63	3.62	3.02	3.25	7.22	3.84	4.48	3.17	.25	.97	1.31	35.78
1881....	1.34	3.49	2.58	2.11	2.43	10.38	3.77	1.36	6.59	7.03	2.83	1.75	45.66
1882....	.84	1.10	2.98	4.00	8.36	8.25	4.55	1.75	1.38	4.29	7.15	2.02	46.67
1883....	1.66	4.67	.75	5.00	6.19	4.77	4.31	1.45	1.19	6.23	3.45	1.45	41.12
1884....	1.05	1.40	4.28	2.08	5.57	4.03	3.63	5.77	5.23	6.46	1.57	4.42	45.49
1885....	2.38	2.21	1.25	4.00	4.18	4.81	5.03	7.38	2.85	2.80	.83	2.32	39.07
1886....	4.21	1.43	4.16	2.62	5.05	1.30	.32	2.62	3.05	4.70	.95	.71	31.12
1887....	1.88	4.12	1.14	1.26	2.26	2.10	2.90	2.40	3.49	2.24	.98	3.53	28.30
1888....	1.49	.70	3.10	1.60	6.78	3.82	3.39	7.24	2.00	1.50	4.43	2.84	38.89
1889....	1.43	1.38	.65	4.28	4.17	5.68	6.69	1.15	3.95	1.04	1.65	1.40	33.47
1890....	1.90	1.70	3.29	1.12	3.61	6.68	1.88	2.35	2.52	4.24	1.38	1.20	31.87
1891....	1.75	2.19	3.50	1.30	2.51	4.87	3.29	5.20	1.35	1.49	1.50	2.51	35.26
1892....	1.35	1.08	3.90	4.31	10.32	8.83	3.85	1.70	.47	.82	2.21	2.56	42.30
1893....	1.35	1.60	3.49	5.33	2.35	3.61	2.59	1.02	5.05	1.14	2.40	1.27	31.20
1894....	1.80	1.25	2.44	5.33	2.05	2.04	.24	2.74	5.85	2.10	2.99	.76	29.59
1895....	1.83	.84	1.75	.83	3.05	.98	7.82	4.22	2.12	1.02	2.12	2.62	29.20
1896....	1.10	1.18	1.32	5.72	5.21	2.02	5.59	4.43	1.63	1.89	1.09	1.27	34.45
1897....	5.46	2.72	2.80	5.23	1.59	2.54	3.51	1.21	2.50	.78	2.07	1.94	32.35
1898....	3.33	1.72	3.64	3.74	5.30	3.34	.73	6.22	2.34	3.74	1.76	.51	36.37

¹ Values taken from surrounding stations.

TABLE 8.—*Monthly precipitation, in inches, Muscatine, Iowa—Continued.*

Year.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
1899....	.38	1.52	1.75	3.18	7.61	2.35	2.67	3.14	1.08	1.24	1.52	2.21	28.65
1900....	1.72	2.65	3.86	2.02	4.05	1.57	3.65	6.31	4.31	1.96	1.36	.99	34.45
1901....	1.46	1.63	2.81	1.81	1.26	4.50	1.44	.40	2.17	.99	.95	1.72	21.14
1902....	.59	.95	2.33	2.14	4.66	8.79	7.93	8.94	4.21	3.28	3.28	2.41	49.51
1903....	.58	1.72	2.01	3.76	6.80	3.46	4.79	5.13	5.26	1.82	.97	.99	37.29
1904....	2.27	.71	2.65	2.83	2.87	2.35	3.52	6.44	2.14	1.01	.20	2.43	29.42
1905....	.72	2.15	1.42	3.08	2.84	6.73	2.81	3.52	1.17	4.05	2.41	.87	31.77
1906....	3.12	2.91	3.12	1.88	3.76	3.89	1.96	2.75	2.78	1.42	2.55	1.69	31.83
1907....	4.78	.49	2.55	2.35	8.26	4.66	8.80	5.20	2.55	1.49	.97	.81	42.91
1908....	.66	2.03	2.17	2.34	6.10	3.86	3.72	8.77	2.02	2.10	2.80	.56	37.13
1909....	2.19	2.30	1.58	5.46	3.35	4.43	3.63	2.61	1.96	1.68	5.53	2.90	37.62
1910....	1.73	.74	.36	2.40	4.39	2.62	3.04	3.17	2.80	.66	.42	.96	23.29
1911....	1.38	3.91	.95	3.45	2.65	2.33	4.35	3.11	8.58	2.48	4.22	2.02	39.43
Mean	1.90	1.97	2.66	3.36	4.40	4.46	3.87	4.28	3.55	2.64	2.40	2.06	37.58

TABLE 9.—*Monthly precipitation, in inches, Peoria, Ill.*

Year.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
1855....												3.76	.....
1856....	0.80	1.03	0.25	1.72	4.03	1.50	2.83	1.39	0.76	1.66	4.00	6.13	26.10
1857....	.37	5.33	3.84	1.39	2.80	2.77	1.40	5.61	2.16	2.01	1.33	1.50	30.51
1858....	1.48	1.95	3.28	6.25	10.64	5.95	5.75	3.24	2.96	3.24	4.85	3.67	53.26
1859....	1.50	1.42	5.82	2.60	3.17	2.18	.67	4.14	2.84	2.15	2.40	1.23	30.12
1860....	1.86	2.40	1.13	1.64	2.00	4.95	8.87	2.39	2.00	.70	3.13	3.08	34.15
1861....	1.25	2.46	3.96	4.95	2.19	2.31	2.31	2.78	3.72	2.33	1.09	.94	30.29
1862....	4.27	.70	2.71	5.03	1.46	3.67	7.74	9.04	5.09	1.61	1.81	5.20	48.33
1863....	2.83	3.20	2.61	1.52	2.97	.45	4.82	2.24	2.51	3.92	.71	4.49	32.27
1864....	1.42	.41	2.20	4.81	1.88	2.55	2.92	1.56	4.81	1.53	3.82	3.06	30.97
1865....	.22	4.01	3.57	4.27	2.34	1.86	5.77	3.61	8.31	1.67	.31	1.08	37.02
1866....	3.21	1.10	2.54	2.65	2.57	2.61	5.17	3.97	6.50	2.87	.51	2.05	35.75
1867....	1.36	2.88	1.74	1.57	4.40	2.92	2.65	2.26	.60	1.10	1.93	1.21	24.62
1868....	.77	.75	5.38	3.18	7.85	1.43	1.47	2.74	4.46	1.41	4.50	1.81	35.75
1869....	.99	2.62	1.71	3.59	6.09	8.35	7.35	3.39	.74	1.53	3.13	2.63	42.12
1870....	2.05	.33	4.37	.45	1.62	.75	.68	3.26	3.56	4.27	1.21	1.02	23.57
1871....	2.45	1.62	3.24	2.58	1.93	3.47	3.76	4.95	.65	3.37	2.09	2.04	32.15
1872....	.20	.69	2.50	2.95	2.38	9.76	7.80	4.54	4.13	.80	2.00	1.07	38.82
1873....	3.47	1.29	1.30	4.76	4.78	2.96	4.25	1.25	3.65	2.26	1.46	7.15	38.58
1874....	3.04	1.45	1.11	2.90	2.51	1.95	1.46	5.60	1.15	1.00	2.20	.67	25.04
1875....	.32	2.20	2.05	2.00	4.23	3.00	8.28	1.02	9.63	3.46	.71	2.39	39.29
1876....	2.60	2.00	4.70	2.66	3.94	6.17	5.54	3.14	4.51	4.86	2.63	.28	43.03
1877....	.92	.06	3.32	2.86	2.57	9.43	3.01	2.04	2.83	5.68	3.65	3.45	39.82
1878....	.50	2.25	2.10	3.75	4.45	3.49	2.58	4.42	.97	3.96	.91	2.08	31.46
1879....	1.05	.97	1.80	2.95	.93	3.23	3.42	1.88	3.72	2.17	4.93	1.92	28.97
1880....	3.38	3.95	3.30	5.94	6.73	2.32	3.17	3.38	3.09	1.75	1.92	.96	39.89
1881....	.52	3.51	3.52	1.62	3.50	7.20	2.43	1.38	4.05	5.56	4.26	3.50	41.05
1882....	1.27	3.21	3.12	2.41	6.34	11.18	2.91	1.92	1.53	3.76	2.08	1.76	41.49
1883....	1.31	4.14	.77	6.18	6.54	4.39	3.57	.57	2.93	3.57	4.19	1.37	39.53
1884....	.70	3.18	2.17	2.62	5.50	3.87	3.67	4.13	5.76	4.80	2.19	3.21	41.80
1885....	2.63	.87	.24	4.44	1.70	4.07	4.73	2.64	5.28	2.32	1.04	2.44	32.40
1886....	2.41	1.86	2.25	2.75	2.90	3.67	.47	3.57	4.68	1.81	1.34	.89	28.60
1887....	1.10	5.45	.94	1.53	1.24	1.53	2.85	2.72	2.53	2.14	1.62	3.65	27.30
1888....	1.87	1.66	4.03	1.18	6.72	1.84	6.48	2.30	4.79	2.29	2.67	2.39	38.22
1889....	1.70	.84	1.50	2.79	3.92	6.30	7.64	1.23	2.61	2.28	2.91	1.33	35.05
1890....	2.80	1.36	2.73	2.33	2.74	2.42	.72	2.39	2.12	3.45	1.79	.41	25.26
1891....	1.68	1.90	2.68	3.64	1.97	3.31	2.82	5.71	2.00	.71	4.08	2.39	32.89
1892....	1.25	1.84	2.45	4.54	7.70	6.05	3.08	.73	2.35	1.20	2.72	1.75	35.66
1893....	.87	2.92	3.01	7.86	4.65	1.82	2.48	.44	3.02	.70	2.21	1.74	31.72
1894....	2.60	1.48	3.06	2.22	3.58	4.18	1.00	2.50	4.42	1.45	2.92	1.58	30.99
1895....	1.32	.37	1.02	2.89	1.84	1.67	8.72	2.27	4.92	.67	4.17	5.86	35.72
1896....	1.30	1.95	1.05	4.47	5.74	2.23	7.02	4.69	4.86	.23	2.20	.40	36.14
1897....	5.39	1.19	4.70	2.87	1.29	2.11	4.65	1.02	.93	.04	3.48	1.16	28.83
1898....	4.08	2.59	5.74	3.02	5.54	3.37	.47	3.26	6.05	3.00	2.03	.93	40.08
1899....	.72	1.96	2.97	1.36	6.03	2.60	1.69	1.27	5.24	2.78	2.25	2.12	30.99
1900....	1.92	5.64	1.42	1.09	5.54	1.44	2.45	5.39	2.94	2.90	1.87	.39	32.99
1901....	1.98	1.24	4.31	.81	1.50	4.32	3.97	1.29	2.64	.90	.80	2.26	26.02
1902....	.67	1.41	2.71	2.29	2.99	9.60	7.30	7.42	6.78	3.78	2.83	1.54	49.32
1903....	.89	1.70	3.66	5.15	4.22	2.39	4.91	7.22	5.78	2.13	.85	.95	39.85
1904....	1.87	1.29	4.42	3.48	4.06	2.44	5.58	4.13	6.67	.10	.12	1.33	35.49
1905....	1.15	1.45	2.00	3.99	4.53	5.13	4.24	1.36	1.78	2.77	2.45	1.60	32.45
1906....	1.70	1.85	2.65	2.77	2.88	3.24	2.48	1.59	4.92	1.00	2.42	1.65	29.05
1907....	5.39	.14	2.34	2.82	2.08	3.99	4.89	6.60	2.94	.35	1.68	1.66	34.88
1908....	.59	3.98	2.50	4.08	7.76	4.09	3.94	2.78	.82	.71	1.89	.82	33.96
1909....	1.55	3.67	1.81	7.17	3.72	3.56	4.57	.79	3.68	3.59	5.53	2.50	42.14
1910....	1.97	1.10	.52	3.56	4.49	.78	3.23	.68	3.12	1.69	.79	1.25	23.18
1911....	2.37	2.39	2.64	2.69	1.03	6.64	2.58	1.73	12.30	2.65	3.01	2.13	42.16
Mean	1.77	2.06	2.66	3.21	3.83	3.77	3.95	3.03	3.75	2.26	2.35	2.14	34.78

TABLE 10.—*Monthly precipitation, in inches, St. Louis, Mo.*

Year.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	An- nual.
1830							4.97	12.25	5.16	5.79	1.28	0.55	-----
1831	2.08	1.06	4.58	4.39	1.95	1.34	1.88	2.51	1.99	6.76	4.08	3.68	36.30
1836							3.66	6.51	5.90	2.59	4.20	5.02	
1837	.84	1.35	3.13	2.34	3.00	3.46	2.48	2.73	2.85	.79	1.96	2.01	26.94
1838	3.72	1.11	1.51	3.36	1.68	3.73	3.13	4.47	.06	3.06	2.09	.44	28.36
1839	2.21	2.50	2.59	5.46	7.93	7.26	5.71	2.89	2.45	3.96	2.48	2.00	47.44
1840	1.80	1.38	2.10	3.31	4.58	6.27	2.36	7.15	3.96	6.30	1.73	.71	41.65
1841	.84	.88	4.99	3.85	2.38	1.67	3.09	5.63	3.22	6.81	5.44	3.93	42.73
1842	.45	3.90	2.21	3.48	3.22	5.12	1.76	2.64	2.17	2.57	2.38	2.39	32.29
1843	2.34	1.90	3.49	4.87	4.15	3.95	2.49	1.32	2.19	1.55	4.82	1.72	34.79
1844	3.36	1.73	4.84	3.86	11.26	6.85	8.13	.45	.30	2.25	1.17	1.61	45.81
1845	1.83	1.07	3.18	2.28	4.42	10.01	4.75	6.23	1.03	1.16	1.10	.93	37.99
1846	2.98	1.27	1.27	4.84	3.75	5.21	.84	4.73	4.84	2.71	2.11	10.90	45.45
1847	2.12	3.58	2.28	3.98	4.36	8.61	5.37	.90	3.26	8.74	8.63	.89	52.72
1848	1.86	2.27	6.61	3.16	8.10	17.07	5.37	9.74	1.12	2.41	1.91	5.74	65.36
1849	4.18	.56	2.70	2.64	2.71	6.46	9.40	5.15	5.81	2.17	2.11	1.82	45.71
1850	1.94	4.10	5.63	7.68	7.47	1.47	4.83	2.10	3.74	2.71	6.24	2.59	50.50
1851	.61	6.74	3.14	4.70	2.83	6.19	1.77	8.97	.49	1.51	1.99	3.90	42.84
1852	.99	2.12	7.67	2.28	5.19	10.25	3.36	1.60	1.47	5.26	3.29	3.48	46.96
1853	.52	1.67	.79	3.24	3.64	3.23	4.10	5.48	4.67	.96	1.51	1.08	30.89
1854	1.18	3.11	7.49	7.60	6.30	3.21	.92	1.80	1.44	4.15	1.94	1.49	40.62
1855	4.66	.70	2.89	2.65	7.46	4.27	5.17	6.53	3.89	3.89	5.16	3.10	50.37
1856	1.03	3.64	1.06	6.35	3.03	1.24	4.61	6.32	3.51	2.10	4.90	4.29	42.08
1857	.41	7.74	1.80	1.72	4.81	3.71	2.82	4.15	3.18	3.02	3.80	1.87	39.03
1858	3.42	2.12	3.96	6.07	10.64	6.69	8.03	2.87	3.86	7.73	4.92	8.52	68.83
1859	2.32	5.35	7.32	4.89	6.60	11.02	5.54	2.93	4.44	1.80	5.43	3.76	61.40
1860	1.80	2.60	1.16	2.03	2.29	6.58	2.97	2.96	2.11	1.58	1.63	2.08	29.79
1861	1.16	2.01	7.38	3.18	4.39	4.96	2.04	3.44	4.14	2.85	1.39	1.09	38.03
1862	4.01	.80	4.11	4.82	2.51	2.85	3.61	1.32	6.27	3.73	3.59	6.38	44.00
1863	4.11	3.99	3.02	1.55	2.68	3.16	2.51	6.93	1.56	4.76	2.15	4.03	40.45
1864	2.74	.82	1.71	5.58	3.90	.41	3.60	4.91	2.82	3.15	5.25	2.72	37.61
1865	.87	3.75	8.61	3.31	5.66	5.21	7.94	1.97	2.60	3.33	.00	3.63	46.88
1866	4.16	2.24	2.80	1.56	2.24	5.59	3.68	3.71	10.53	2.01	1.37	1.87	41.75
1867	2.28	4.81	2.37	.53	8.26	5.64	3.71	2.29	.17	1.31	2.74	3.65	37.76
1868	1.71	.55	7.66	7.08	3.96	1.58	2.03	8.53	5.25	2.11	2.04	3.09	45.59
1869	2.02	2.49	4.24	4.61	3.60	6.25	2.49	5.51	1.70	3.42	7.48	3.16	46.97
1870	2.25	.33	2.76	2.39	2.73	1.38	1.59	6.55	1.14	3.35	1.94	2.76	29.17
1871	2.53	2.92	1.27	.49	3.15	2.51	1.64	3.55	.25	2.07	1.83	1.17	23.28
1872	.64	1.15	2.43	2.77	6.04	4.28	4.59	.93	3.38	.55	2.01	1.70	30.47
1873	3.53	1.52	2.10	6.88	5.73	6.68	5.96	.07	3.02	3.27	1.64	5.10	45.50
1874	3.14	3.66	4.36	3.44	3.70	2.00	5.71	4.70	2.30	1.09	2.32	1.46	37.88
1875	.54	2.59	4.08	2.53	5.48	10.84	9.50	2.66	.24	1.23	.89	2.42	43.00
1876	4.75	2.86	6.90	2.25	3.13	3.43	5.90	5.03	7.63	1.66	1.74	.18	48.46
1877	1.24	.88	3.41	3.03	3.11	8.69	2.88	2.61	3.56	4.92	3.76	3.34	41.43
1878	3.36	1.69	2.79	6.74	4.63	2.40	3.92	4.75	3.42	3.27	1.38	3.48	40.83
1879	1.64	1.48	1.92	2.31	.95	4.04	1.97	2.23	1.34	.68	4.30	2.84	25.70
1880	3.83	2.65	2.51	3.31	3.44	2.56	5.17	1.53	3.10	2.09	2.67	1.80	34.66
1881	.49	4.16	1.95	3.14	3.96	2.74	2.13	.31	3.14	7.21	6.74	1.40	37.37
1882	2.80	8.94	3.49	3.58	4.55	4.53	3.84	2.20	1.73	2.44	3.24	1.81	43.15
1883	.94	5.88	2.29	3.31	2.89	5.04	4.31	3.34	.01	6.60	3.71	1.78	40.10
1884	.79	4.43	3.00	4.15	2.68	4.52	2.86	1.21	6.04	2.48	2.30	6.18	40.64
1885	3.26	.87	.40	4.84	2.80	7.68	2.58	2.96	8.98	7.51	1.68	2.03	45.59
1886	3.11	1.71	3.04	2.10	7.84	7.09	.55	2.44	9.60	.85	3.36	2.65	44.34
1887	.65	3.68	3.54	4.36	5.27	2.54	2.74	1.14	2.47	.76	4.61	3.54	35.30
1888	2.15	2.39	3.79	1.88	3.81	8.09	2.09	6.66	1.31	2.59	4.40	2.01	41.17
1889	3.04	4.78	1.62	1.68	3.80	4.72	2.02	.85	3.54	1.65	4.43	1.03	33.16
1890	7.47	2.86	5.99	4.05	5.81	3.18	.37	2.43	1.80	.86	1.55	1.32	37.69
1891	1.35	2.95	2.29	2.29	2.73	5.97	1.50	2.75	1.43	.65	5.30	1.32	30.53
1892	1.52	4.89	1.92	7.60	7.87	2.73	4.64	1.75	1.59	1.66	3.46	1.99	41.62
1893	.33	2.98	5.10	10.84	5.42	3.49	2.49	.65	3.69	1.66	1.36	1.32	39.33
1894	2.56	2.88	2.69	2.68	3.61	1.12	1.35	1.66	3.11	1.56	1.49	2.73	27.44
1895	1.65	.43	2.82	.46	3.16	2.46	7.26	2.08	2.01	.23	3.98	4.66	31.20
1896	1.43	2.81	2.03	2.43	9.12	4.57	4.67	2.12	2.42	1.20	3.70	1.05	37.55
1897	3.75	2.67	8.25	4.66	1.59	5.32	3.23	.66	.09	.31	6.21	3.43	40.17
1898	4.53	1.71	7.73	3.85	8.55	3.85	7.44	.87	3.23	4.34	2.07	1.03	49.20
1899	1.66	3.40	3.96	1.98	6.32	2.32	4.54	2.77	1.27	2.89	1.95	1.55	34.61
1900	.65	5.09	1.45	1.83	4.47	2.62	3.85	1.30	2.68	2.07	3.10	.40	29.51
1901	1.12	1.86	2.94	2.35	2.69	3.92	1.47	.76	.64	2.12	1.21	3.72	24.80
1902	1.18	.83	4.50	2.49	3.04	7.86	2.34	5.20	1.98	2.00	3.20	3.81	38.43
1903	1.76	3.14	3.20	2.79	2.08	5.71	2.68	6.16	3.06	1.37	.61	1.25	33.81
1904	3.15	.84	7.87	3.25	2.88	4.64	3.09	2.62	2.97	.50	.54	1.36	33.71
1905	2.47	1.12	2.35	2.32	4.67	2.72	4.42	2.58	5.56	6.64	1.63	2.06	38.54
1906	3.57	2.92	4.53	1.98	2.61	2.80	.98	3.72	4.40	1.25	4.67	2.09	35.52
1907	7.35	1.12	2.39	3.65	5.57	4.96	3.32	4.36	1.57	3.15	1.89	2.06	41.39
1908	2.08	3.39	3.43	3.84	7.72	3.02	4.24	1.55	1.24	.21	2.83	.64	34.19
1909	3.20	3.94	3.69	6.18	5.99	2.63	7.34	.66	4.22	3.40	4.36	1.89	47.50
1910	2.73	3.22	.14	4.09	5.23	4.24	4.21	1.90	6.09	3.98	.30	1.18	37.31
1911	.85	3.02	2.22	7.46	2.26	1.34	.64	3.51	7.09	2.63	3.44	1.67	36.13
Mean	2.27	2.67	3.55	3.70	4.53	4.74	3.70	3.42	3.11	2.85	2.85	2.58	39.83

In each of Tables 8, 9, and 10 the maximum for each month is shown by heavy-faced figures, as is also the yearly maximum. It will be noted that the greatest mean monthly rainfall is in June in two cases and in July in the other, thus showing that the maximum rainfall is to be expected during the months when farming operations are at their height. The mean annual precipitation for the three stations is 37.39 inches. A study of the tables has shown that a monthly rainfall of 6 inches occurs a little oftener than once each year. A monthly rainfall of 8 inches occurs once in 3.5 years, and one of 10 inches once in 11 years. A rainfall of 15 inches during a period of two successive months occurs once in 3.6 years. It would appear from these figures that a pumping plant should be able to handle a monthly rainfall of at least 8 inches.

Table 11 shows the average number of storms per year, of the given intensities, for short periods of from 1 to 10 days, that may be expected in the section under consideration. This table was obtained from a study of the daily precipitation records of Muscatine, Peoria, and St. Louis.

A study of the rainfall records of Muscatine, Peoria, and St. Louis shows that about two-thirds of the storms of the various intensities given in Table 11 occurred from April to September, inclusive, the months during which crops are most injured by occasional flooding. During the six months from October to March, inclusive, occasional flooding of the land would do little if any damage in the section under consideration. Therefore the storms occurring during the winter months may be disregarded in the determination of the proper capacity of pumping plant. This can be done by reducing the number of storms of each given intensity by one-third. For instance, Table 11 shows that on the average a storm of 2 inches in two days occurs three times a year. Only two of these storms occur at a time of the year when damage to crops would be caused by flooding.

TABLE 11.—Average yearly number of storm periods of from 1 to 10 days' duration.

[Based upon daily precipitation records of the United States Weather Bureau for Muscatine, Iowa, 1854-1914; Peoria, Ill., 1856-1914; and St. Louis, Mo., 1843-1914.]

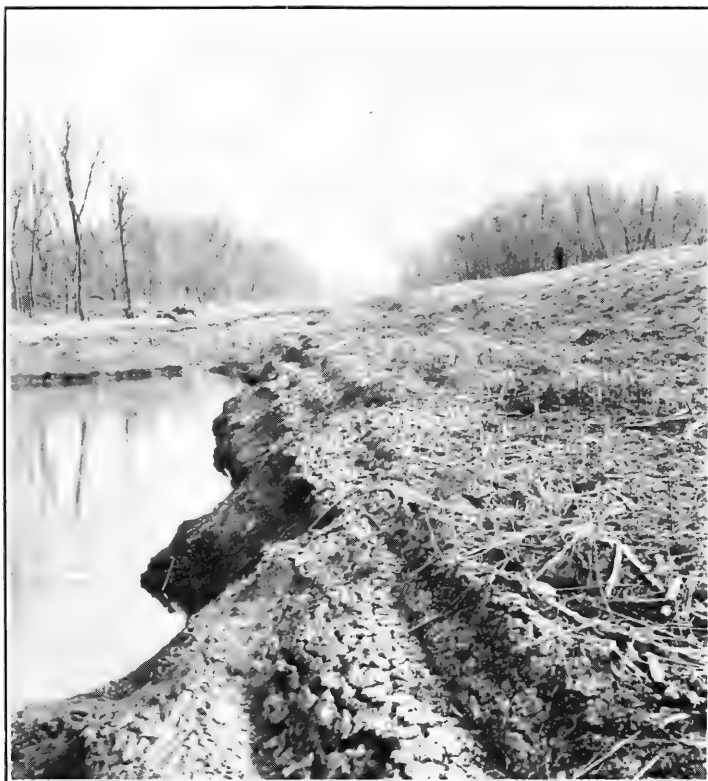
Total rainfall.	Average number of storms per year.									
	1-day period.	2-day period.	3-day period.	4-day period.	5-day period.	6-day period.	7-day period.	8-day period.	9-day period.	10-day period.
2 inches.....	2.018	3.059	3.615	4.071	1.580	1.722				
3 inches.....	.479	.900	1.172	1.456	.651	.775				
4 inches.....	.172	.320	.438	.545	.290	.355	.847	.444		
5 inches.....	.041	.083	.142	.160	.195	.290	.355	.444	0.479	0.520
6 inches.....	.012	.024	.041	.047	.071	.077	.100	.118	.165	.207
7 inches.....		.006	.012	.018	.030	.047	.053	.059	.071	.077
8 inches.....					.006	.006	.012	.024	.024	.030
9 inches.....						.006	.012	.018	.018	.018
10 inches.....								.006	.006	.006



FIG. 1.—HYDRAULIC FILL LEVEE UNDER CONSTRUCTION.
PIPE DISCHARGING SAND AND WATER.



FIG. 2.—FINISHED HYDRAULIC FILL SAND LEVEE.



LEVEE CONSTRUCTED BY DRAG LINE EXCAVATOR, MUSCATINE-LOUISA
LEVEE AND DRAINAGE DISTRICT.

Note earth barriers across borrow pit,



FIG. 1.—SLUICE GATE IN OPERATION, ONE GATE OPEN, DES MOINES COUNTY DRAINAGE DISTRICT NO. 1.



FIG. 2.—SUCTION SIDE OF LAZWELL PUMPING PLANT OF DES MOINES COUNTY DRAINAGE DISTRICT NO. 1.



FIG. 1.—CROP OF 1910, COAL CREEK LEVEE AND DRAINAGE DISTRICT.



FIG. 2.—HOOD BASIN, COAL CREEK LEVEE AND DRAINAGE DISTRICT.



FIG. 1.—MAIN DITCH, COAL CREEK LEVEE AND DRAINAGE DISTRICT.



FIG. 2.—BRANCH A, COAL CREEK LEVEE AND DRAINAGE DISTRICT.

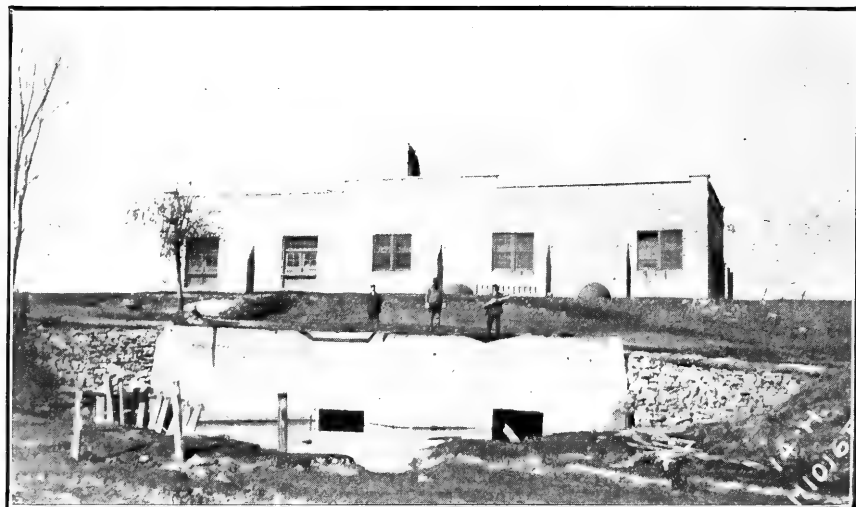


FIG. 1.—PUMPING PLANT AND DISCHARGE BAY, LOUISA-DES MOINES DRAINAGE DISTRICT.

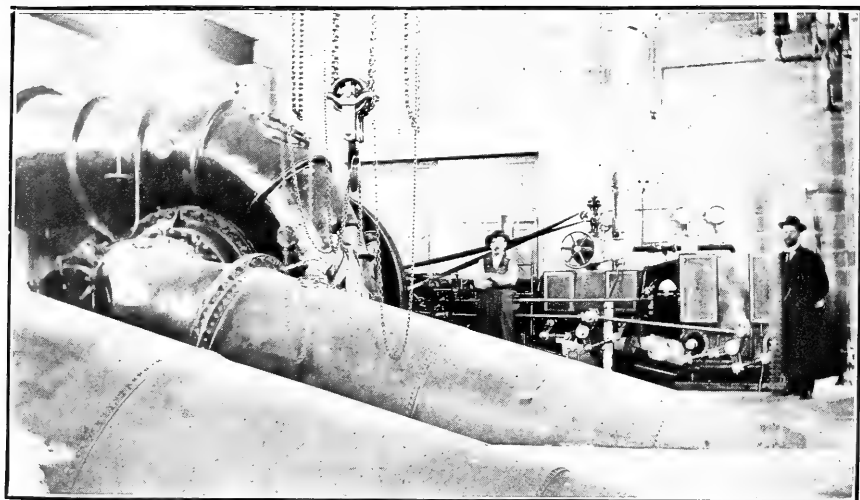
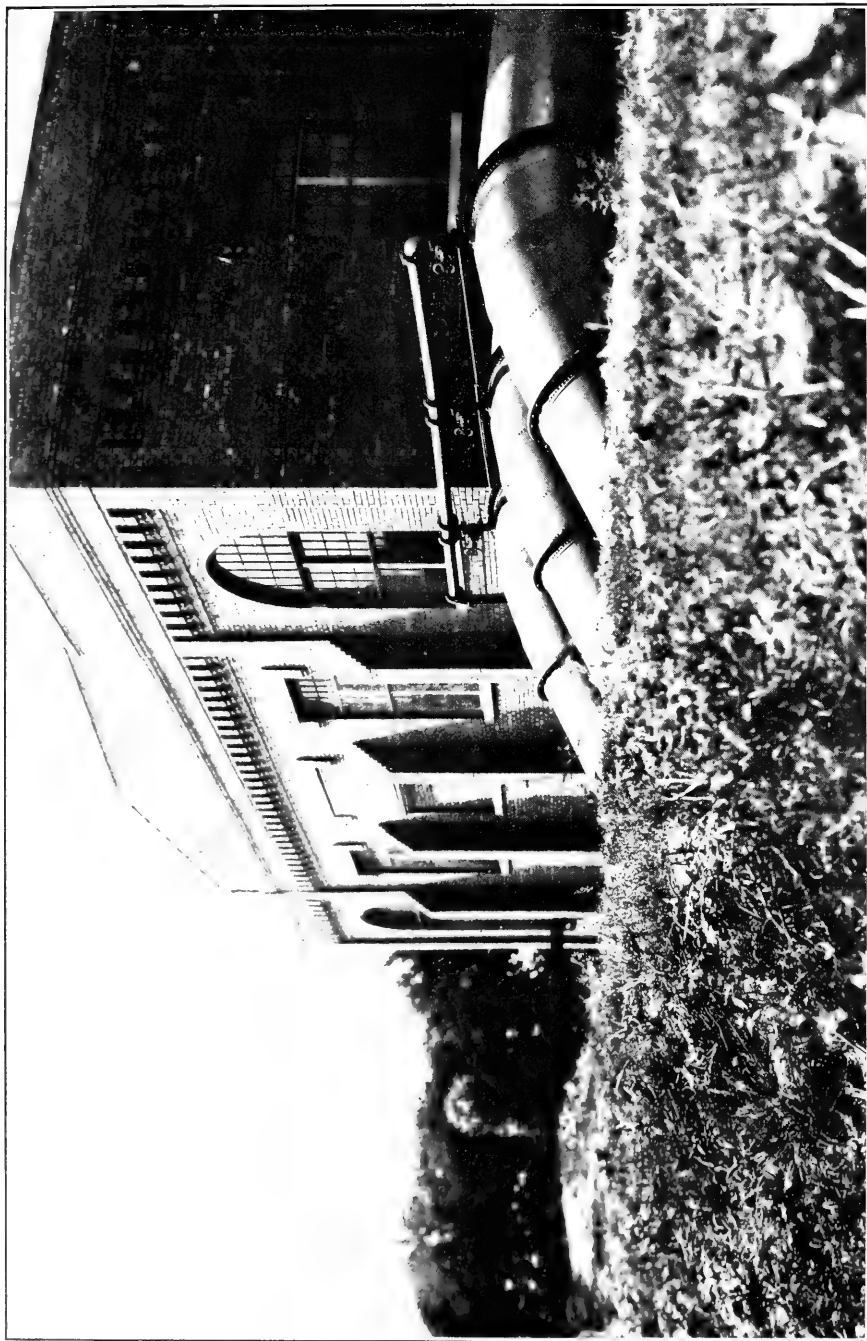


FIG. 2.—ENGINE ROOM, LOUISA-DES MOINES DRAINAGE DISTRICT.



VIEW OF DISCHARGE PIPES OF LAZWELL PUMPING PLANT OF DES MOINES COUNTY DRAINAGE DISTRICT No. 1.



FIG. 1.—REAR OF PUMPING PLANT, LOUISA-DES MOINES DRAINAGE DISTRICT, SHOWING SUCTION PIT.



FIG. 2.—WOODEN FORMS FOR CONCRETE SUCTION PIPES FOR PUMPING PLANT ON MUSCATINE-LOUISA LEVEE AND DRAINAGE DISTRICT.

It is considered that it will be of value to introduce at this point the results of very careful and extensive investigations of rainfall and run-off on pumping drainage districts in southern Louisiana. While various local conditions are different, it is believed that for the six summer months mentioned above the relations between the rainfall and the run-off are quite similar; that is, in both sections the same percentage of the rainfall would appear as run-off. A total of 45 heavy storm periods occurring in southern Louisiana were therefore selected and the results averaged. The average precipitation during the storms selected was 4.90 inches over an average period of six days. The average run-off from these storms was 2.45 inches, distributed over a period of 7.5 days. An increase of another day in the period over which the run-off was taken would have increased the total run-off very little, while a decrease of a day in the average period of run-off would have decreased the total run-off very materially. Very few of the storms included in this list occurred after a prolonged dry period, while perhaps 20 per cent of them followed periods of rainfall that had saturated the soil. Therefore the result undoubtedly is somewhat too large, and if provision be made for such a percentage any error will be on the safe side. It will be noted that the period covered by the run-off figures is one and one-half days longer than the length of the average storm. The districts from which these records were taken average about 2,500 acres in area. As most of the districts in the upper part of the Mississippi Valley are much larger than this, it is assumed that the time required for the run-off to reach the pumping plant will be somewhat increased; therefore in the discussion following the difference between the length of the storm period and the length of the period during which 50 per cent of the rainfall would run off is assumed to be two days instead of one and one-half days, as found for the districts in southern Louisiana. It will be noted in the above table for storm intensities that a 4-inch rainfall during a three-day period occurs a little less frequently than once in two years. Decreasing this frequency by one-third, as explained above, a 4-inch rainfall in a three-day period would occur in the growing season once in three years. Fifty per cent of it, or 2 inches, would appear as run-off in five days. The average storage capacity of the canals and ditches on such districts is about 0.25 inch; thus 1.75 inches of water would have to be pumped in five days to prevent flooding, requiring a pumping capacity of at least 0.35 inch per 24 hours.

If it were considered that flooding of the lower portions of the district to a small depth for 24 hours once in three years would not be greatly injurious, the time for removing the water could be made six days, requiring a capacity of 0.29 inch. It is believed that a

capacity of about 0.30 inch per 24 hours would be satisfactory on most districts. Districts of less than 5,000 acres might better increase this somewhat, while it is possible that districts having more than 15,000 acres could decrease this capacity with safety. By applying a similar process to any other storm intensity, the necessary capacity to prevent flooding could be approximated. In cases where especially valuable crops were to be raised it might well pay to provide for storms that occur only once in 10 years.

While run-off data on pumping districts in this section were not extensive enough to draw any very definite conclusions, the majority of the districts have a capacity of plant sufficient to remove a depth of 0.25 inch in 24 hours. On most of the districts this capacity has given satisfaction.

LOCATION OF PUMPING PLANT.

In general the pumping plant should be so located that the drainage water may be brought to it with the least expenditure for interior ditches. However, a more expensive ditch system will often permit the combination of several small districts into one large one, thus reducing very materially the charge for pumping-plant construction and operation. The expenditures should be adjusted so that the annual charge for interest on investment, depreciation, and operation of pumping plant will be a minimum. Where convenient, there is some apparent advantage in locating the plant on a suitable arm of the river rather than on the main river channel. The location should be so chosen as to be most easily accessible for the delivery of fuel and for convenience of attendance. Thus, in the Pekin-La Marsh District the pumping plant is situated at the upper end of the district, so as to be close to the town of Pekin.

TYPES OF PUMPING MACHINERY.

Since pumps are to be depended upon to remove promptly surplus water whose presence may endanger a whole crop, it is of the utmost importance that the pumping plant be able to work with certainty and reliability whenever needed.

The annual cost of a pumping plant is made up of three main items: (1) The charge for interest on the original cost of the plant and for depreciation; (2) the cost of fuel, or electricity if motors are used; and (3) the cost of labor. Certain general principles concerning the mutual relations of these different items must be understood before taking up the comparison of the different types of machinery available for pumping.

The interest upon the original cost of the plant goes on every year whether the plant is operated much or little. Depreciation also takes place whether the plant is operated or not, and for such installations

as are under discussion it probably does not depend much upon the length of time the plants are in operation each year. What amount to allow for depreciation is a difficult matter to decide. The length of time before such machinery will wear out depends chiefly upon the original quality of the installation and the care that is taken of it afterwards. We can not safely assume that such machinery will last more than 20 or 25 years. Much of it will be discarded sooner, either because it is outgrown or worn out. With proper care it is probable that such machinery may be made to endure twice as long as it will last if it is carelessly treated. It is customary to include with depreciation an item for repairs. This should be very small during the first few years of the life of a well-constructed plant, but will grow larger as the plant becomes older.

The cost of fuel per year depends to a considerable extent upon the kind of machinery used and also upon the amount of time the plant is run. Whenever a steam plant starts there is a certain consumption of fuel in preparation before starting, the heat value of which is lost when the plant is stopped. Hence, since the operation of a pumping plant is very intermittent, the fuel consumption is not strictly proportionate to the time run. The amount of fuel used also depends largely upon the skill of the fireman. An unskillful man may easily use 25 per cent more fuel than is really necessary. Different types of equipment require different amounts of fuel to produce the same result; that is, some types are more economical of fuel than others. The cost of the labor at the pumping plant depends upon the class employed and the length of time it is required. The cost of electricity per year depends on the type of pump and the care used in installation, as well as upon the total time the plant is run. The distance from the transmission lines of the large power companies will influence the power rate. On the larger districts the power rate is usually less than on the smaller ones.

In general, in a given location, that type of pumping plant will be best which requires the least annual cost, including all the elements enumerated above. To a certain extent, variations in these different elements tend to offset each other. For example, a highly efficient plant from the point of view of fuel economy is complicated and expensive, and hence will have a relatively high charge for interest and depreciation. Likewise, it will require skillful and high-priced attendance, but may, on the other hand, in a large plant, require fewer men. If cheap labor is employed, the coal and repair bills will be increased and the deterioration of the plant will be more rapid. The advantage of fuel economy is relatively more important in locations where fuel is especially high, and in a large plant than in a small one, but in any plant it diminishes in importance as the time of running per year decreases or becomes much interrupted.

The above principles have long been regarded as fundamental in the science of mechanical engineering design. Applying them to drainage pumping, where the work is usually confined to a small portion of the year, the labor available is cheap and unskilled, and the other conditions are not favorable for effective care of the plant, the fundamental requirements in a drainage pumping plant are reliability and simplicity.

The centrifugal pump is the kind most often used for drainage. It is simple, has no valves, and can be obtained in all sizes. Its disadvantages are, that it must be primed in starting, that it can operate satisfactorily under a given set of conditions only within a narrow range of speed, and that its efficiency when operated under practical conditions that obtain in drainage pumping is not high. Recently pump manufacturers have given more attention to the design of centrifugal pumps for drainage pumping, and the newer pumps are better fitted for such service. In order to work economically and to maintain a uniform capacity, the speed must be varied with the changes in the total head under which it operates. The size of the centrifugal pump is usually given as the diameter of the discharge opening—for example, a 24-inch pump is one having a discharge pipe 24 inches in diameter as it leaves the pump. Most large pumps are made with a horizontal shaft and are called horizontal pumps. When larger than 24 inches they frequently have a double suction, thus bringing water to both sides of the impeller; this has the advantage of balancing the side thrust on the impeller and shaft. Without this arrangement some automatic balancing device must be used in connection with the impeller and a collar thrust bearing on the shaft.

The capacity of a pump is usually reckoned by assuming the water to have a velocity of 10 feet per second through the discharge opening of the pump. However, some manufacturers base the rated capacity of their pumps upon an assumed velocity of 12 feet per second. While it is possible to obtain a velocity of 10 feet per second through the discharge opening of the pump by the use of proper speed at the various heads, as the pumps are usually operated in practice the discharge is often 20 per cent less than the theoretical rating. This is due to underestimation of the power required for the various heads pumped against; as the head increases the speed must also be increased. During the high-water stages of 1913 on the Illinois River several plants had their capacity reduced about 50 per cent because the engines were not large enough to turn the pumps at the requisite speed. If enough power is furnished, the capacity of the centrifugal pump can be pushed as much as 25 per cent above its rated capacity with a relatively small loss in efficiency. Tests of such plants have been made which showed the amount pumped to exceed the rated

capacity by 50 per cent, but at this overload the efficiency of the pump is but a small part of its best figure.

Rotary displacement pumps and plunger pumps have occasionally been used for pumping drainage water, but they are not adapted to this use. They may have a very high mechanical efficiency, but their cost more than offsets this advantage. Scoop wheels have been extensively used in England and Holland, and to some extent in this country in Louisiana. They may be made to have a higher efficiency than centrifugal pumps, especially for very low lifts, but they are not adapted to locations where the head is subject to wide fluctuations. A full description of the construction and operation of these scoop wheels has been given by W. W. Wheeler.¹ Another publication² describes a recent large and successful installation in Holland, and gives the results of tests.

Recently large screw pumps have been installed for the pumping of drainage water from districts in Louisiana. One district of about 9,000 acres has installed and is operating two such pumps, each having a diameter of discharge pipe of 78 inches. The city of New Orleans recently contracted for and is now installing 12 such pumps for the disposal of drainage water; these have diameters of discharge of 12 feet. The impeller in the screw pump is a segment of a screw and is somewhat similar to a boat propeller, except that it has many more blades. On the discharge side diffusion vanes take the water from the blades of the impeller and change its partly spiral motion to one which is parallel with the axis of the discharge pipe. It is expected that such a pump will operate more satisfactorily under changing heads than will a centrifugal pump, and for very large installations it is cheaper than a centrifugal pump of equal capacity.

SOURCES OF POWER.

Steam, gas, and electricity are all used as sources of power for pumping plants. In Illinois soft coal is abundant and cheap, though in some places crude oil or natural gas may be found more available. A suction gas producer with a gas engine has been tried, but such a plant requires hard coal or coke for fuel, which greatly increases the expense. Furthermore, such a type of plant is not adapted to intermittent working. Electricity is by far the most convenient source of power where it is available, but in general it will be considerably more expensive than using coal to produce steam. Its convenience will perhaps offset its cost, especially for a small plant. In the latter part of this bulletin, under the heading "Amount and cost of pumping," data from a number of districts are given which show the com-

¹ *The Drainage of Fens and Low Lands by Gravitation and Steam Power.* London and New York, 1888.

² *Engineering News*, 63 (1910), No. 20, p. 581.

parative cost of power in the various districts. These data indicate that where cheap coal or gas is available steam is the most economical source of power.

Return tubular, marine, locomotive-type, and water-tube boilers have all been used. For a small plant the locomotive type or the simple return tubular boiler is simplest and cheapest. For plants of over 200 horsepower water-tube boilers have decided advantages, though they may cost somewhat more than the simpler fire-tube boilers. The boilers of all large plants should be kept constantly insured by some reliable boiler insurance company.

KIND OF ENGINE OR MOTOR.

Either vertical or horizontal engines may be used. When possible, it is best to have the pump directly connected to the engine. This is usually not feasible for a pump smaller than the 24-inch size, because such a pump would require too high a speed of the engine. In this case the pump must be driven by a belt or a rope. The engine should be condensing and, if large, should be compound. A high-speed automatic engine is more difficult to operate with inexperienced labor than a slow-speed engine, but it has the advantage of being smaller and lighter for the same power than the slow-speed engine of the Corliss or some similar type. In general, however, the high-speed engine is not as economical of steam as the slow-speed type. The engine should be provided with a governor able to keep it from racing if the entire load is suddenly removed. The engine should be adjustable for a considerable range of speed, should be able to carry a considerable overload, and should work as economically as possible through a wide range of load. As will be explained more fully below, it is especially desirable that an engine for this work should be capable of very flexible operation.

If a motor is used to drive the pump, it should be of the constant-speed slip-ring type. If the motor is direct-connected to the pump or is connected by some means that does not allow the speed ratio to be changed, the pump will work satisfactorily at only one head; that is, the head suitable to the fixed speed. If the lift be higher, the quantity pumped will be much reduced, while if the lift be lower the quantity will be much increased, the efficiency lowered, and danger of overloading the motor will be incurred. Manufacturers have recently placed on the market a centrifugal pump with a modified screw-type impeller which requires about the same horsepower for a rather wide range of heads. The screw pump previously described also has this feature. Both the screw pumps and the centrifugal pumps with the modified screw-type impeller have been connected to motors with a fixed-speed ratio, such as by the use of gearing, and have worked satisfactorily. However, as the head increases the

quantity pumped must decrease. Along the upper Mississippi and the Illinois River the greatest demand on the pumping plant usually occurs at the time when the head pumped against is greatest. If the speed of the pump be fixed to give full capacity at the greatest head, at lower heads the discharge of the pump will be greatly increased and the efficiency much lowered. As the average lift will be much lower than the maximum, usually scarcely half, the yearly efficiency of the pump will be small and the consumption of power large. By far the better method is to connect the pump and the motor by means of a belt with three sizes of pulleys or with silent chain drive with two or three sizes of sprocket wheels. The pump speed can then be altered to suit the head. In Louisiana, where the fixed-speed ratio is used, the greatest demand on the pumping plant occurs at the lowest head, and as the head increases the amount of water to be pumped greatly decreases; consequently the capacity of the pump fits the need.

AUXILIARIES.

The steam plant will require the usual auxiliaries. A surface condenser will furnish pure feed water, but some form of jet condenser is simpler and cheaper. For priming the pumps a steam ejector is the simplest arrangement, though an air pump may be used. Separators and traps, filters and heaters, should be used as needed for safe and economical operation. Piping and boilers should be well covered, to reduce as much as possible the amount of radiation and condensation of steam.

In large plants boilers, engines, and pumps should all be divided into two or more equal-sized units, so arranged that they can, when necessary, be operated independently, and the auxiliaries should be installed in duplicate.

CALCULATION OF THE SIZE OF PUMPING PLANT.

To illustrate the method of determining the size of machinery to be installed in a pumping plant, the calculation will be made for a district of 10,000 acres. To remove a depth of water of one-fourth inch over the whole district in 24 hours will require a capacity of 105 cubic feet per second. For such a district it will be best to use two separate pumps, which should be identical in size. A 30-inch pump will be rated at about 49 cubic feet per second, a 32-inch pump at about 56 cubic feet per second, and a 36-inch pump at about 71 cubic feet per second. In this case it would be best to use two 32-inch pumps, which would seem to have a slight margin of excess capacity. However, since pumps of this style so frequently fail to have the capacity assumed, they should be taken only under the guaranty of the manufacturer and subjected to a thorough test after they are installed. The pumps will need to be run at about

200 revolutions per minute, and hence may be directly connected to two separate engines.

Assume that the difference between the river-surface level outside the district and the desired ground-water level within the district will vary from a possible maximum of 20 feet during spring floods to nothing in the late summer. The machinery must have sufficient power to pump against the highest head, although much of the time it will run against a lower head. This is a disadvantage, so far as the efficiency of the machinery is concerned, because every engine runs most efficiently at about its rated capacity, and if it is either overloaded or underloaded its efficiency is reduced. The actual head against which the pumps must force the water, sometimes called the dynamic head or the hydraulic head, is always greater than the difference in water level as described above, which is called the static head. This increase is due to the friction of the water in the suction and discharge pipes and the so-called velocity head—that is, the head necessary to start the water into motion in the pipes. The friction in pipes carrying water at a high velocity is greatly affected by the kind of pipe used and the smoothness of the interior surface, and hence can not be predicted with certainty. For a velocity of 8 feet a second the friction in 200 feet of 48-inch pipe would probably amount to 2 feet of head and in a 24-inch pipe to at least 6 feet of head. A bend of 90° adds probably a foot to the friction head. The velocity head amounts to about 1 foot, and if the water passes around a sharp edge in entering the suction pipe there is probably a loss of another foot of head. To be safe, then, we should assume the addition of at least 6 feet to the static head to give the head on the pump. Another small amount might be added to the lift on account of the lowering of the water level in the supply ditch when the pumps are being operated. But it is probably better to ignore this last addition and assume that during the short time when the river is at maximum flood stage the water level in the district will not be pumped down quite to its normal level rather than to provide extra capacity for the very short and infrequent periods of maximum river floods.

With a total head of 26 feet the hydraulic horsepower is calculated by multiplying together the lift (26 feet), the number of cubic feet of water per second (105), and the weight of 1 cubic foot of water (62.5 pounds), and dividing by 550. In this case the result is 310. The power required of the engine will be greater than this amount, depending upon the efficiency of the pumps, which for these conditions should be at least 60 or 70 per cent. For this case probably manufacturers would be willing to guarantee an efficiency under test of 70 per cent. Accordingly the maximum brake horsepower required of the engines would be 440. Engines suitable for this

work should be able to carry continuously an overload of 25 per cent without an increase of speed and without a great loss in steam economy; hence, if 440 horsepower puts this overload on the engines, their normal rating would be 350 brake horsepower. They should develop sufficient power at the speed at which the pump has the best efficiency for a static lift of 10 feet or a dynamic lift of 16 feet, in this case about 270 horsepower. When the pumps operate at the maximum lift, their speed should be increased in order to maintain the discharge and the efficiency of the pumps, and the engines should be adjustable and so constructed as to run safely at the higher speed. Since increasing the speed of itself increases the power developed by the engines, this gives a margin of safety in the capacity of the engines. If two separate engines and pumps are used, each engine should have a brake horsepower of 175. Its indicated horsepower will be from 10 to 20 per cent greater. An engine should run fairly economically down to three-fourths of its rating. These units, then, would be economical of fuel down to a static lift of 10 feet. Records of plant operation on districts on the Illinois River show that this is quite near the average pumping head. As the above plant is designed, when the lift falls below 5 or 6 feet the steam used by the engine will be much increased in proportion to the useful work actually performed in lifting the water. This disadvantage is not very important for plants on the Illinois River, but for districts on the Mississippi River, at least for those above Burlington, Iowa, where records were available, it is of very great importance, as the mean lift is quite often less than 5 feet. Records from the Louisa-Des Moines Drainage District No. 4 show the following average static lifts: 1910, 4.20 feet; 1911, 2.82 feet; 1912, 5.20 feet; 1913, 5.74 feet. As will be shown later in this bulletin, under the heading "Amount and cost of pumping," the cost per unit of water lifted 1 foot was greatly increased in 1911, when the lift was very low. Where the average lift is as low as 5 feet and the maximum static lift is as great as 20 feet, it would be very difficult to install an engine that would work with economy at the low head and deliver the full capacity of the pump at the highest head. In the above example, for service on the Mississippi River it would be better to install a smaller engine than one with a nominal rating of 350 brake horsepower and to work it at a heavier overload than 25 per cent at the maximum head. Such an engine would then work at about three-fourths of its nominal rating at a static lift of 6 feet and would not lose much in economy of steam consumption.

In case it were desired to drive the pump by a motor, the calculations for the maximum required horsepower would not differ from those in the foregoing example. However, as the motor is not capable of an overload its nominal rated horsepower must be large enough to

provide for the maximum demand. The question of adjustment of speed has already been discussed.

If it were desired to provide for a greater depth of water removed per 24 hours, the proper additions could be made to the above results.

The boiler capacity required would depend upon the particular engines used, upon the number and kind of auxiliaries, and upon the quality of coal to be used. For a plant of this kind, however, the nominal boiler horsepower should be at least as large as the rated engine horsepower. The boilers must have a capacity amply sufficient to supply safely all the steam needed by the engines when operating at their maximum overload. This may be secured by additional boilers or by forcing the boilers, when necessary, through appliances for producing an artificial draft. In general, large engines of the best types require less steam per horsepower than smaller ones. In a very large plant the nominal boiler horsepower may be less than the engine horsepower.

In designing such a plant, all the elements must be carefully calculated to secure in each the necessary maximum capacity. It is especially needful that the auxiliaries be large enough. A deficiency in some single comparatively slight but essential element may hinder the operation of the whole plant. Durability and reliability in workmanship and materials may be secured to some extent by specifying that the boiler shall be capable of operating at a higher pressure than its regular working pressure, and that the engines shall be able to run with higher steam pressures and at higher speeds than the normal. Descriptions of a large number of pumping plants and the results of tests are given in detail in a previous bulletin.¹

BUILDINGS AND FOUNDATIONS.

The machinery should be inclosed in a substantial and durable building. The foundation of the building, and especially of the machinery, should be prepared with great care. As the soil conditions are very likely to be bad, careful investigations should be made by means of borings. Nothing should be assumed. Failure to make such borings has many times resulted in great difficulties during construction, and in at least one case in failure after completion. The results of such investigations will sometimes show that the proposed site of the plant must be changed. Drainage district officials who are responsible for the construction of the plant should not only make certain that the proposed foundation will prove satisfactory under the prevailing soil conditions, but should allow only those to do the work who are experienced in building foundations under such adverse conditions. Inexperienced con-

¹ U. S. Dept. Agr., Office Expt. Stas. Bul. 183, Mechanical Tests of Pumps and Pumping Plants used for Irrigation in Louisiana in 1905 and 1906.

tractors often have underbid others who have become familiar with foundation construction under such circumstances, and the former have been awarded the contract. However, such bids often prove to be the highest, because of delays, unsatisfactory results, and even forfeiture of contract. Often the expense of foundation is a large part of the cost of the completed plant. When properly constructed it is the most permanent part of the plant, and should outlast the building and serve as the support for several sets of machinery.

ARRANGEMENT OF SUCTION AND DISCHARGE PIPING.

Proper arrangement of the suction and discharge pipes is essential to the economical and reliable operation of the plant. The pipes should be as direct as possible. All bends should be of long radius, and the interior of the pipes should be as smooth as practicable, in order that the lost work, due to friction, may be small. Since the head consumed in overcoming friction varies as the square of the velocity, the larger the piping the less the friction loss. The piping should be made large enough to reduce the velocity in the pipe to as near 5 feet per second as practicable. All changes in size and direction of the piping should be gradual, and at no point should the water be permitted to flow around a sharp corner.

The suction pit should be carried to a greater depth than the main canal, even though this results in some danger of excessive seepage and of opening springs or boils through the lower layers from the river when the suction pit is close to the river bank. This has been a frequent source of difficulty in pumping plants, and on this account the discharge pipe should be made longer than it often is. The sides of the suction pit should be protected by a reinforced-concrete wall supported by round piling, and usually a cut-off wall of sheet piling should be driven along the center lines of these side walls. If the material in the bottom of the pit is inclined toward quicksand, or if there are springs and boils, the bottom as well as the sides of the pit should be of reinforced concrete well tied down by the use of round and sheet piling, as it must be remembered that there will be an upward pressure on the bottom of the pit when the water is lowered. The pit should be shaped to form a suitable gradually-curved entrance to the suction pipe, and should be provided at its outer end with a steel screen. The screen openings should be of such size that the velocity through them, under normal conditions, would not be more than 1 foot per second.

In order that the suction lift may be kept low, the pump should be set as low as is consistent with securing good foundation, ease of installation, and safety after installation. In general, the plant should be at such an elevation as would make it very unlikely that excessive rainfall or suspension of pumping would cause the water

ever to rise high enough to interfere with its operation. In a certain district on the Illinois River it became necessary to protect with a levee the pumping plant and its immediate grounds from the remainder of the district.

There are various arrangements of pipes for taking the water from the suction pit to the pumps, but there are a number of features in addition to those already mentioned which apply to most of the designs. The suction pipe should be perfectly air-tight and so strong as not to collapse under the greatest suction that will be put upon it. The entrance should be expanded so as to provide for a gradual contraction of the stream of entering water. The curvature of the expanded end may be relatively abrupt, but should be smooth, so that the water shall not flow swiftly past any sharp edge or angle. In general, in contracting a stream there is no loss of head, even if the reduction in cross section be comparatively sudden, so long as the surfaces are smooth and without sharp angles. If the entrance end of the pipe is cut horizontally, the edge must be at least as low as the lowest level to which the water in the suction pit is to be reduced, and it would be better if it were a foot lower. Below this edge there should be a clear distance to the bottom of the pit equal to one or one and one-half times the diameter of the suction pipe. If the entrance of the suction pipe is expanded to such a degree that the velocity of the incoming water is not more than 2 feet per second, the water level can be drawn down to the end of the suction pipe without trouble from sucking air. Without such expansion, while the level of the water is still considerably above the end of the pipe, much air will be drawn into the pump, with a consequent loss of efficiency and danger of losing the priming. Neglect to provide ample waterway around the entrance to the suction pipe has been a source of much annoyance to pumping plants. If the end of the suction pipe is cut vertically the lower side of the pipe should be at or near the bottom of the pit. As the water can not be lowered to a level very near the top of the pipe without the latter sucking air, the entrance should be oblong in shape, with its greatest diameter horizontal. Small whirlpools will often form over such pipes and allow air to enter. This condition is likely to give the most trouble as the water nears the top of the pipe but before there is any appreciable velocity of the water in the suction pit toward the pipe. When the water is low enough in the pit to have an appreciable velocity toward the pipe the small whirlpools will be swept into the pipe before they are of sufficient size to admit air. Where these whirlpools cause the pumps to lose their priming a remedy has been to place a large raft of timbers in the pit in such a manner that whirls can not form directly over the end of the pipe.

One arrangement of pipe which is much used is to place the suction pipe on a uniform slope from the pump to its lower end in the suction pit. This slope should be flat enough to allow of the pipe being supported rigidly. The end of the pipe can be cut horizontally, making an oblong opening, or the end of the pipe can be turned down in an elbow of large radius; such an arrangement is used on the plant of the Louisa-Des Moines Drainage District No. 4. (See fig. 2.) Again, the pipe can be curved until it is horizontal and the end cut vertically. Another arrangement is to bring the suction pit directly under the pumps and have a short vertical pipe with an expanded horizontal end. Especially if there are two or more pumps close together, the area of the suction basin will be rather limited and a great many cross currents will be set up. When such pumps are in operation this turbulent condition of the water in the suction pit is very noticeable. The efficiency of the centrifugal pump is seriously affected if the water approaches the impeller in this condition. Riveted steel pipes are universally used for the above-mentioned designs. The metal in the pipes should be special low-carbon steel, so that it will better resist corrosion. After erection the pipes should be heavily coated with an asphalt paint.

The use of reinforced concrete for suction pipes is just commencing. Figure 3 shows the plan of the pumping plant being constructed on the Muscatine-Louisa Levee and Drainage District, which has concrete suction pipes built into the foundation. As the suction elbows on the pumps, and the yoke which connects them with the concrete pipe, are of cast iron, this construction of suction pipe should be permanent, with very little if any depreciation. Figure 2 of Plate VIII shows the forms for these concrete pipes. It will be noted from figure 3 that these pipes do not extend into the suction pit; consequently the water, as it approaches the entrance to the pipes, has no chance to pass the edge on the outside of the pipe and cause eddies. As the edges of the entrance are rounded the water that approaches along the wall or bottom of the suction pit does not have to turn a sharp angle. The entrance losses for these pipes should be less than in any of the others described and the water should approach the impeller of the pump in a condition favorable to the best pump efficiency.

The discharge pipe also should be strong enough to resist any suction pressure that may be put upon it. It should be gradually expanded, immediately after leaving the pump, so as to reduce the velocity to as near 5 feet per second as seems practicable. It must be remembered, however, that in expanding the cross section of a stream so as to reduce its velocity the changes must be very gradual; otherwise there will be loss of energy due to the impact of the rapidly moving stream against the more slowly moving mass of water.

Practice is not uniform as to the best method of preventing water from flowing back through the pipes into the district from the river when the pumps are not operating. Some prefer to carry the dis-

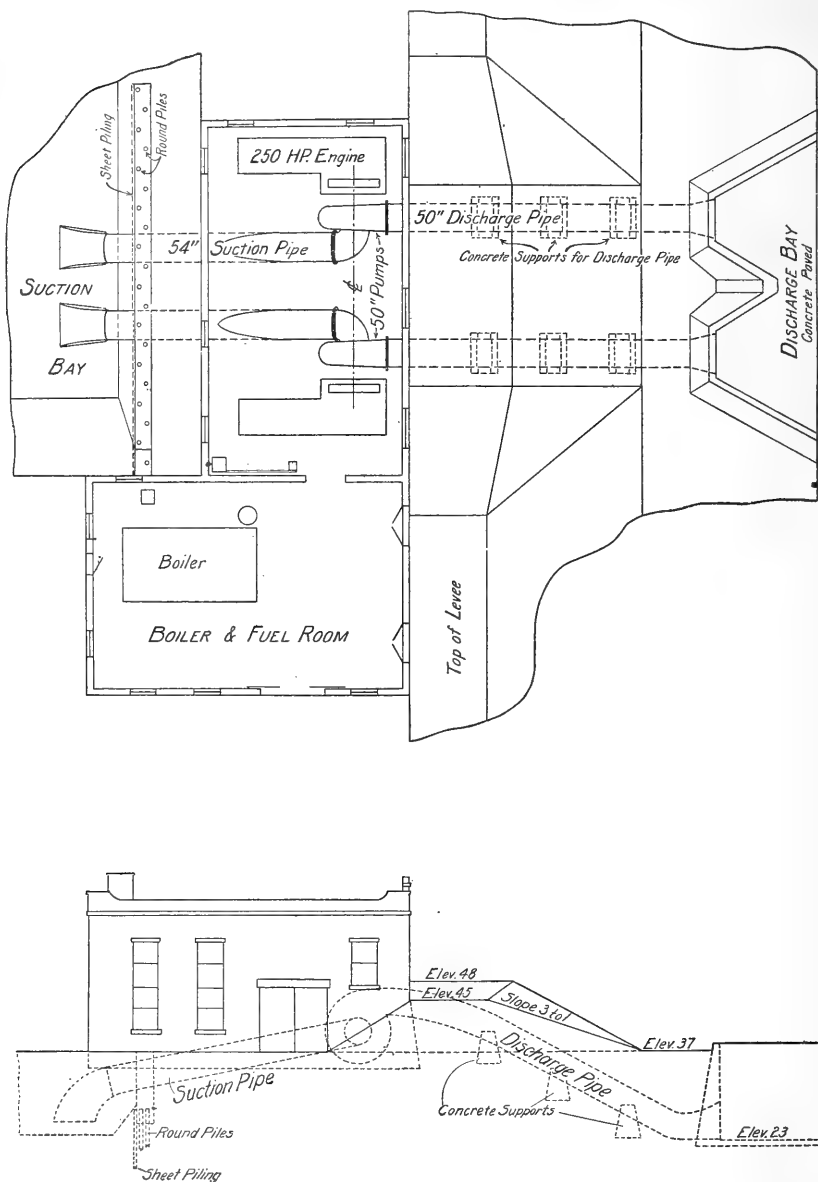


FIG 2.—Plan and elevation of pumping plant, Louisa-Des Moines Drainage District No. 4, Iowa.

charge pipe through the levee above high water and then down, with its end opening below low-water line, so as to secure a water seal. This is necessary in order that the pipe may act as a siphon and that

hence the static head on the pump may be only the difference in level between the water in the canal and the water in the river. In this case the pipe must have an opening at the highest point for use in priming the pump. This opening will also be used to admit air to break the seal, thus preventing water from flowing back by siphon

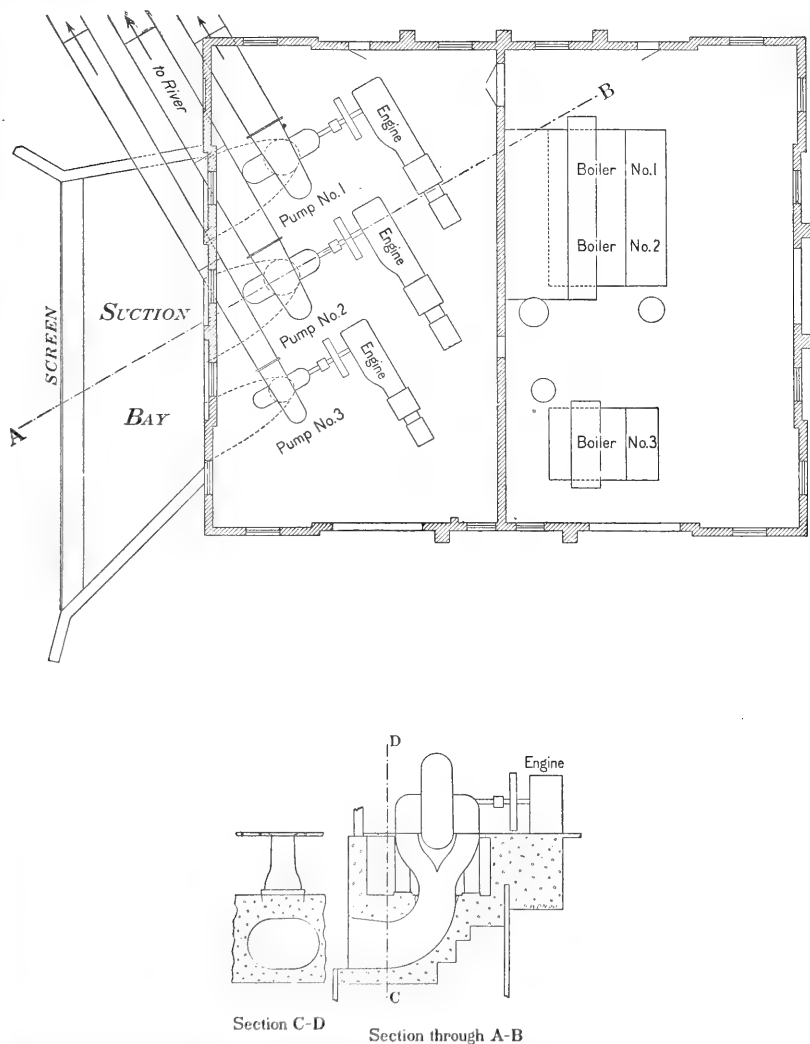


FIG. 3.—Plan and elevation of pumping plant in Muscatine-Louisa Levee and Drainage District, Iowa.

action when the pump is stopped. If the pumps equipped with this type of discharge pipe are driven by motors, a flap valve should be used on the end of the pipe to prevent the water from siphoning back through the pump while it is being primed, thus turning the motor backward and overloading it. This valve need not fit tightly and

will be of use principally when the water in the river is high. Some arrangement should also be made for continually exhausting the air from the highest point in the discharge pipe; otherwise air will collect, the pipe will not run full, and the perfect siphon action will be interfered with. By connecting the top of the pipe with a large receiver under vacuum, equipped with a water-gauge glass, the condition of the pipe can always be easily observed and pumping of air will be only necessary at intervals.

Others prefer to carry the discharge pipe through the levee on a level. This necessitates the installation of a gate valve in the pipe next to the pump. If the pipe is not over 2 feet in diameter, a flap valve might be used on its outer end; but such a valve is never entirely reliable and certain in its operation, and its use is not recommended. A gate valve must be of the slow-closing type, as it is dangerous to the plant to close such a valve quickly. If the pipe is carried through the levee, all the precautions that were mentioned in the section on gravity sluiceways should be used to prevent seepage along the pipe. The outlet end of the pipe must have adequate protection against river wash and against undercutting by the water discharged by the pump.

Attention has already been called to the plans of the Louisa-Des Moines and the Muscatine-Louisa pumping plants (figs. 2 and 3). Plate VI and figure 1 of Plate VIII are views of the Louisa-Des Moines pumping plant. Figure 1 of Plate VI is a view from outside the levee, showing the front of the building and the discharge bay. Figure 2 of the same plate is a view of the engine room, giving a good idea of the size of the 50-inch centrifugal pumps, each of which is direct-connected with a tandem compound condensing engine of 250 horsepower. Figure 1 of Plate VIII is a view of the rear of the building, showing the levee beyond and the enlarged ends of the suction pipes.

Plate III, figure 2, and Plate VII are two views of the Lazwell plant of the Des Moines County Levee and Drainage District No. 1. Plate III, figure 2, is a view of the suction side of the plant, showing concrete suction basin, steel screen across the portion of the pit where the water goes into the pumps, and the discharge pipes curving out of the building, over the levee, and downward. Plate VII is a closer view of the discharge pipes as they turn down through the top of the levee to the river channel to the left. These views illustrate the easy curves used in such pipes. In Plate VII the small pipes connected to the top of the discharge pipes are used in priming the pumps and also in exhausting the air that collects in the top of the pipes while the pumps are operating.

AMOUNT AND COST OF PUMPING.

Table 12 shows the yearly rainfall and amounts pumped for the four districts already mentioned under "Necessary capacity of pumping machinery." It will be noted that there is considerable variation in the relation between rainfall and amount pumped for different years on the same district, and for the different districts during the same year. The average percentage of the rainfall pumped was 40.6 per cent if based upon the total yearly rainfall, or 46.7 per cent considering only the rainfall during the months when pumping was going on. The average annual rainfall for the above four stations for all the years available was only 26.21 inches, while the average annual rainfall for the Weather Bureau stations at Muscatine, Peoria, and St. Louis is 37.39 inches. Assuming that the ratio would be the same, 40.6 per cent, if the rainfall were normal, we might expect the amount to be pumped as a depth of 15.18 inches. Moreover, as the percentage of the rainfall appearing as run-off is usually greater during wet years than in dry ones, the above figure would more likely be less than the average run-off rather than greater. Those districts which do not have gravity sluices may well expect to do more pumping than those which have, although most of the rainfall and pumping occur at the time of the year when the rivers are high.

TABLE 12.—*Annual rainfall and amounts pumped.*

District.	1912			1913			1914			Total.			Per cent of rainfall in run-off.	
	Rain-fall. ¹	Rain-fall. ²	Run-off.	Rain-fall. ¹	Rain-fall. ²	Run-off.	Rain-fall. ¹	Rain-fall. ²	Run-off.	Rain-fall. ¹	Rain-fall. ²	Run-off.	Rain-fall. ¹	Rain-fall. ²
Louisa - Des Moines.....	In. 25.67	In. 15.07	In. 15.15	In. 28.16	In. 14.84	In. 11.32	.....	.....	.....	In. 53.83	In. 29.91	In. 26.47	49.1	88.5
Pekin - La Marsh.....	34.49	34.49	13.41	26.05	26.05	11.80	20.85	20.85	4.87	81.39	81.39	30.08	37.0	37.0
East Peoria.....	.....	.....	.....	.....	.....	.....	22.75	22.75	6.98	22.75	22.75	6.98	30.8	30.8
Coal Creek.....	.....	.....	.....	.....	.....	.....	25.50	25.50	10.98	25.50	25.50	10.98	43.6	43.6
Average.....	30.08	24.78	14.28	27.11	20.44	11.56	23.03	23.03	7.61	26.21	22.79	10.64	40.6	46.7
Per cent of rainfall in run-off.....	47.5	57.6	.....	42.6	56.6	.....	33.0	33.0	.....	40.6	46.7	.....	.....	.....

¹ Total rainfall for year. ² Rainfall for months during which drainage was secured by means of pumps.

The cost of operation of pumping plants for drainage pumping will vary largely according to type of machinery and the method of operation. While the cost of operation of various types of machinery is well understood, the conditions obtaining on the average drainage district are likely to affect seriously the accepted cost figures. In view of this fact cost data were obtained from a number of drainage pumping plants now in operation. The operating expenses were classified under "Labor," "Fuel," "Repairs," "Supplies," and "Superintendence." Tables 13 and 14 give the cost of such items, per acre per year, for a number of districts. As some districts have

a greater proportion of hill water than others, the cost has been shown for the assessable area and for the total drainage area of each district. The tables state the number of years of operation the cost figures cover, and if not otherwise stated, 1914 is the last year included. Table 13 is for steam-driven plants and Table 14 for electrically-driven plants.

It will be noted that the average yearly cost per acre of total drainage area for the steam-driven plants is \$0.43, and that the variation in cost is from a maximum of \$0.93 for the Coal Creek District to a minimum of \$0.15 for the Des Moines County No. 1 District. Of course, great variations in the amount of water pumped and in other local conditions tend to affect the relative costs for the various plants. Where the pumps are driven by motors the average yearly cost per acre of drainage area is \$0.88, with a maximum of \$1.07 for the Pekin-La Marsh District and a minimum of \$0.63 for the Big Swan District.

TABLE 13.—*Costs of operation—Steam-driven plants.*

District.	Number of years' operation.	Average cost per acre per year.											
		Labor.		Fuel.		Repairs.		Supplies.		Superintendence.		Total.	
		A. ¹	T. ²	A.	T.	A.	T.	A.	T.	A.	T.	A.	T.
Nutwood.....	5	\$0.115	\$0.082	\$0.158	\$0.113	\$0.015	\$0.011	\$0.038	\$0.027	\$0.079	\$0.057	\$0.405	\$0.290
Eldred.....	1	.129	.126	.153	.150	.019	.017	.028	.027	.....	.....	.329	.320
Hillview.....	5 (1913)	.190	.126	.278	.185	.047	.031	.032	.021	.114	.076	.661	.439
Big Swan.....	7 (1913)	.123	.098	.250	.200	.032	.026	.031	.025	.071	.056	.507	.405
Meredosia.....	9	.100	.069	.314	.238	.023	.017	.020	.015	.073	.055	.530	.394
Crane Creek.....	4	.173	.154	.281	.250	.014	.012	.049	.043	.....	.....	.517	.459
Coal Creek.....	5 (1913)	.331	.300	.598	.540	.049	.044	.041	.037	\$.012	\$.010	1.031	.931
Lacey.....	4 (1905)	.072	.072	.247	.247	.030	.030	.017	.017	.....	.....	.366	.366
Do.....	2 (1910)	.151	.151	.416	.416	.017	.017	.027	.027	.....	.....	.611	.611
Spring Lake.....	5	.181	.103	.306	.175	.024	.014	.081	.046	.138	.079	.730	.417
Louisiana-Des Moines.....	2 (1913)	.164	.133	.204	.165	.041	.033	.027	.022	.048	.039	.484	.392
Des Moines County No. 1.....	2 (1913)	.140	.053	.162	.062	.034	.013	.033	.012	.036	.014	.405	.154
Average.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.432

¹ Based on assessable area.² Based on total drainage area.³ Partial.TABLE 14.—*Costs of operation—Electrically-driven plants.*

District.	Number of years' operation.	Average cost per acre per year.											
		Labor.		Power.		Repairs.		Supplies.		Superintendence.		Total.	
		A. ¹	T. ²	A.	T.	A.	T.	A.	T.	A.	T.	A.	T.
Big Swan.....	1	\$0.116	\$0.098	\$0.592	\$0.473	\$0.000	\$0.000	\$0.000	\$0.000	\$0.071	\$0.056	\$0.779	\$0.627
Lacey.....	2	.....	.....	\$.740	\$.740	.....	.....	.....	.....	.....	.....	.740	.740
Perkin-La Marsh.....	3	.132	.107	\$1.160	\$.940	.021	.018	.002	.002	.....	.....	1.315	1.067
Coal Creek.....	1	.159	.143	.860	.776	.000	.000	.010	.010	.020	.018	1.049	.947
East Peoria.....	1	.504	.244	1.200	.582	.001	.001	.023	.011	.372	.180	2.100	1.018
Average.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.880

¹ Based on assessable area.² Based on total drainage area.³ Cost of power calculated on basis of schedule in effect at the Coal Creek plant.

Tables 13 and 14 do not take into account the fixed charges, which include interest, depreciation, taxes, and insurance. In computing the fixed charges interest has been assumed at 6 per cent, taxes and insurance at 1 per cent, and depreciation at 6 per cent. While the rate of depreciation on the machinery might be somewhat greater than this, the cost of the machinery is only a part of the total cost of the plant, and a rate of 6 per cent is higher than would apply to the building, and especially to the foundation, the cost of which last item is often a large part of the cost of the completed plant. Tables 15 and 16 give the total cost per acre per year for the districts given. As before, two tables are made, one for steam and one for electrically driven pumps.

It will be noted that the average yearly cost per acre of total drainage area is, for steam-driven plants, \$0.78, and that the variation in cost is from a minimum of \$0.40 for the Des Moines County District No. 1 plant to a maximum of \$1.22 for the Lacey plant. Where the pumps are driven by motors the average yearly cost per acre of drainage area is \$1.38, with a maximum of \$1.89 for the East Peoria District and a minimum of \$0.89 for the Big Swan District. As stated above, the amount of water pumped and other local conditions tend to alter the true relation between the costs of operation of the various plants. However, from three districts accurate and detailed records were obtained, so that the cost in operating expense of lifting an acre-foot of water 1 foot could be accurately determined. Table 17 is a statement of amount pumped and the unit cost on these three districts.

Both plants on the Illinois River have a much higher mean lift than has the one on the Mississippi River. A large variation in costs is noted for the different years for the Louisa-Des Moines plant. This can be traced directly to the average lift; the pumps do not work so efficiently at the lower lift. In this respect the plants on the Illinois River have a considerable advantage over the Louisa-Des Moines plant, as their lifts are higher and the pump efficiencies must be much better. In the early part of the discussion in this section it was assumed that under normal conditions the average amount of water to be removed per year was a depth of 15.2 inches. With the unit costs as taken from the actual operating expenses of the three plants given in Table 17, the costs of drainage per acre per year have been calculated and are shown in Table 18. In selecting the unit cost to use for the Louisa-Des Moines plant, the one corresponding to the highest head is taken, so that a better comparison can be made with the plants on the Illinois River. However, the lifts are much higher for the latter plants, thus putting them at a considerable advantage; for if their lifts were as low as that of the Louisa-Des Moines plant their efficiencies would be much decreased

and the unit costs correspondingly increased. The results are calculated for average lifts of 5 and 10 feet. All three of these plants are well built and carefully operated. They are quite representative of their types, and the costs of pumping given in Table 17 should quite closely approximate what might be expected in similar plants operated under like conditions.

TABLE 15.—*Total costs of pumping—Steam-driven plants.*

District.	Horsepower of engines.		Annual fixed charges.	Annual operating expenses.	Assessed area.	Watershed area.	Charges per acre per year on assessed area.		Charges per acre per year on watershed area.		Total charges per acre per year on—	
	First cost.						Fixed.	Operating.	Fixed.	Operating.	Assessed area.	Watershed area.
Nutwood.....	500	\$36,480	\$4,750	\$4,338	<i>Acres.</i> 10,700	<i>Acres.</i> 15,000	\$0.444	\$0.405	\$0.317	\$0.290	\$0.849	\$0.607
Eldred.....	300	28,000	3,640	3,132	9,305	9,500	.391	.337	.383	.330	.728	.713
Hillview.....	300	25,000	3,250	8,140	12,300	18,500	.264	.662	.176	.440	.926	.616
Big Swan.....	300	25,000	3,250	6,084	12,000	15,000	.271	.507	.217	.406	.778	.623
Meredosia.....	200	18,000	2,470	1,995	3,760	5,000	.657	.531	.494	.399	1.188	.893
Crane Creek.....	250	16,000	2,080	2,759	5,340	6,000	.390	.516	.347	.460	.906	.807
Coal Creek.....	200	16,000	2,080	6,912	6,700	7,426	.310	1.032	.280	.930	1.342	1.210
Lacey.....	220	15,000	1,950	1,898	5,200	5,200	.375	.365	.375	.365	.740	.740
Do.....	220	15,000	1,950	1,950	3,200	3,200	.610	.610	.610	.610	1.220	1.220
Louisa-Des Moines.....	500	50,000	6,500	6,280	13,000	16,000	.500	.483	.406	.393	.983	.799
Spring Lake.....	600	60,000	7,800	8,600	12,850	22,500	.607	.670	.347	.382	1.277	.729
Des Moines County No. 1.....	1,230	144,000	18,700	11,570	28,600	75,000	.654	.405	.249	.155	1.059	.404
Average.....												.780

TABLE 16.—*Total costs of pumping—Electrically-driven plants.*

District.	Horsepower motors.		Annual fixed charges.	Annual operating expenses.	Assessed area.	Watershed area.	Charges per acre per year on assessed area.		Charges per acre per year on watershed area.		Total charges per acre per year on—	
	First cost.						Fixed.	Operating.	Fixed.	Operating.	Assessed area.	Watershed area.
Big Swan.....	1,400	\$20,000	\$2,600	\$10,790	<i>Acres.</i> 12,000	<i>Acres.</i> 15,000	\$0.217	\$0.900	\$0.173	\$0.720	\$1.117	\$0.893
Lacey.....	185	10,000	1,300	3,200	3,200	3,200	.406	1.000	.406	1.000	1.406	1.406
Pekin-La Marsh.....	135	7,800	1,000	3,520	2,600	3,200	.385	1.354	.313	1.100	1.739	1.413
Coal Creek.....	300	20,000	2,600	7,027	6,700	7,426	.388	1.049	.350	.946	1.437	1.296
East Peoria.....	125	10,500	1,360	1,570	750	1,550	1.810	2.093	.877	1.013	3.903	1.890
Average.....												1.380

¹ Plant has one 100-horsepower motor and 300 horsepower of steam engine. First cost estimated as if four 100-horsepower motors were installed.

TABLE 17.—*Amounts pumped and unit costs of pumping.*

District.	Year.	Amount pumped.	Average static head.	Cost of lifting 1 acre-foot 1 foot.
		<i>Acre-feet.</i>	<i>Feet.</i>	
Louisa-Des Moines.....	1910	15,900	4.20	\$0.086
Do.....	1911	15,000	2.82	.141
Do.....	1912	20,132	5.20	.064
Do.....	1913	16,002	5.74	.063
Coal Creek.....	1914	6,800	9.40	.110
East Peoria.....	1914	901	7.02	.158

TABLE 18.—*Probable costs of pumping with typical pumping plants.*

District.	Cost of lifting 1 acre-foot of water 1 foot.	Cost of lifting 1.25 acre-feet 1 foot.	Cost of lifting 1.25 acre-feet—		Fixed charges.	Total cost of pumping per acre per year.	
			5 feet.	10 feet.		Lift 5 feet.	Lift 10 feet.
Louisa-Des Moines.....	\$0.063	\$0.079	\$0.395	\$0.79	\$0.406	\$0.801	\$1.196
Coal Creek.....	.110	.137	.685	1.37	.35	1.035	1.72
East Peoria.....	.158	.198	.99	1.98	.877	1.867	2.847

OPERATION AND MAINTENANCE.

It has long been recognized that in the construction of drainage improvements the services of men who make the planning and the supervision of such work a specialty is a business necessity. State drainage laws require that such men be employed on districts organized under the law. It is to be regretted that such laws do not also provide for engineering supervision of the operation of the pumping plant and in the maintenance of all the drainage improvements. The successful and economical operation of the pumping plant and the proper maintenance of the plant and the other drainage improvements require the careful and constant attention of those who are especially fitted by training and experience to do such work. On many districts examined the operating expenses of the pumping plant were unnecessarily large, the drainage improvements were rapidly deteriorating, and large damage had occurred from the partial or complete failure of some of the improvements. Such districts did not have proper supervision.

The present system of having a number of commissioners responsible for the administration of the affairs of the districts is wrong. Much is lost by this division of authority, and responsibility for any feature of the administration is hard to fix. Someone should be hired by the district to have full charge of the administration of the district business, and he should be made entirely responsible for the success of such administration. As an example of the divided authority, the records of one of the districts on the Illinois River showed that in the building of a house for the storage of coal at the

pumping plant more money was spent in commissioners' expenses than in the construction of the storage house. An examination of Table 13, showing the costs of the various items for pumping per acre per year, will show that the lowest cost of operation and also of administration is found on the Des Moines County No. 1 District. This district employed engineering supervision and the business of the district was all in the hands of such supervision.

While the need is great for such supervision over all of the drainage improvements it is especially great for the pumping plant. A good pumping plant will often be wasteful, because it is improperly operated. After installation it should be thoroughly tested at various stages of the river, so that the proper operating conditions can be definitely determined. A competent engineer should be placed in charge of the plant, and he should report daily to expert supervision by a complete system of records. From such records it may be possible to devise improved methods of operation or ways of securing greater economy. Without such records it is impossible for anyone to tell in what particulars the operation of the plant is wasteful or is susceptible of improvement. Such a record should show the time of starting and stopping the pumps each day, the heights of the water levels within and without the district, the speeds of the pumps or engines, and the amounts of the boiler feed water and fuel consumed. It should set forth all incidents of importance in the operation of the plant, and may be kept in a form similar to that shown in Table 19. One page should be used for each day. The gauges should be read before the pumps are started, again as soon as the ditch level has reached a fairly steady state, and at every hour during operation. If more than one pump is in operation the speed of each should be recorded. All additional matters should be recorded in the remarks column. An accurate rainfall record should be kept at every plant. The expenses of operating the plant should be carefully kept under the following headings: Fuel; labor; supplies, such as lubricating oil, waste, etc.; repairs; and superintendence. These expenses should be totaled for each month and for the whole season.

TABLE 19.—*Form for daily pumping records.*

Date,							
Hour.	Ditch gauge.	River gauge.	Lift.	Speed of pump.	Steam pressure.	Rainfall.	Remarks.
	<i>Feet.</i>	<i>Feet.</i>	<i>Feet.</i>	<i>R. P. M.</i>	<i>Pounds.</i>	<i>Inches.</i>	
.....							
.....							
.....							
.....							
.....							

The keeping of proper records for a pumping plant is as important as is bookkeeping for a merchant. Failure to do so will mean loss, just as surely in the first case as in the second. Many districts have already suffered from this omission, and unfortunately very few of the districts are profiting by this costly experience. The landowners within the districts should demand of those in charge that such records be kept.

Many districts have followed the shortsighted policy of employing a cheap man to operate the plant during the pumping season and then allowing the plant to be without an engineer for a large part of the year. Such plants have deteriorated very rapidly and are becoming increasingly more expensive to operate. In the end it is much cheaper to employ a competent man by the year, furnish him with a good house, and make conditions attractive enough to hold the same man for a term of years. The plant on the Louisa-Des Moines District has been operated for about five years; it has been in charge of the same man for the entire period. While the salary paid the engineer has been twice the amount that many other districts pay, it has been money well invested, as the plant is now in almost perfect condition and has the appearance of a new plant. Figures already quoted show that the economy of the plant was better in 1913 than it was in 1910. If by careful operation and maintenance the depreciation of such a plant could be decreased from 6 per cent to 5 per cent, a saving of \$500 a year would be effected. It is certain that the depreciation on many plants which have been carelessly operated during the pumping season and neglected the remainder of the year is at least 10 per cent. On a plant of this size this difference in rates of depreciation would easily pay the salary of a first-class engineer.

PRESENT STATUS OF DRAINAGE BY PUMPING.

Experience on the Illinois and Mississippi Rivers shows that the total cost of adequate general district drainage improvements, including levees, ditches, and pumping plant, has varied between \$20 and \$50 an acre. An average figure for all the districts examined on the Illinois and Mississippi Rivers is about \$30 per acre. The tendency has been in the last few years to take in the more expensive districts and a considerable increase may be expected in the unit cost of reclamation, particularly on the smaller district. The cost of clearing the land and installing field drainage lies between \$5 and \$20 per acre. These figures do not include the cost of tile-draining the land, but merely of providing the necessary field ditches. Hence, in some places the total cost of putting the land into profitable cultivation may be as high as \$50 per acre. The success that has attended drainage of this character is awakening the interest of those in many parts of the United States who own valley lands subject to overflow;

by profiting by the experience of the districts already under drainage, the new districts will undoubtedly save much money and secure more satisfactory drainage improvements. The best way for one unfamiliar with this kind of drainage to become informed on the subject is to visit and inspect thoroughly a number of the completed districts. Tables 20 and 21 give lists of such districts, with information as to location, size, etc.

SUMMARY.

Numerous tracts in units of from 5,000 to 20,000 acres have been reclaimed along the Illinois River and on both sides of the Mississippi in the States of Illinois, Iowa, and Missouri. In the average district the cost of the general drainage improvements, including levees, ditches, and pumping plant, has been about \$30 per acre. This method of reclamation may be expected to be extended constantly to new localities as agricultural land becomes more valuable.

The design and construction of the levees, ditches, and pumping plant require a considerable degree of engineering ability. Poor design may result either in a system so inadequate for its purposes as to render the benefit to the land insufficient to make the undertaking profitable, or it may lead to an expenditure for construction greatly in excess of the amount that could have been made to suffice. In general, the inexperienced tend to underestimate greatly the extent and expense of the work required in such reclamation.

The levees must originally be made of such height and thickness as to afford ample strength and they must also be given careful subsequent attention to secure proper maintenance. The internal drainage ditches should be deep enough to keep the ground-water level at least 3 feet below the surface and their capacity should be sufficient to discharge heavy rains freely to the pumping station. Streams entering the district from higher ground should be diverted around the levees where such a plan is feasible, and provision should be made in such diversion ditches for the collection and storage of silt from hill streams.

The pumping plant should have a capacity sufficient to remove as a minimum amount in 24 hours a quantity of water sufficient to cover the entire district to a depth of 0.3 inch. The capacity should be greater in situations of heavy rainfall and where the run-off of rolling land is received in the district.

The pumping machinery should be so arranged as to reduce to a minimum the work of disposing of the surplus water, and it should be chosen with especial regard to economy and efficiency in operation. Where large fluctuations in the river level are to be expected the machinery must be sufficiently large to operate at the maximum

head, and at the same time must be as efficient as practicable for more moderate heads.

Since it has been shown that the average depth of water to be pumped from such districts per year will be about 15 inches, with well-designed and carefully operated plants the total cost per acre of drainage area per year should not exceed 80 cents for a mean lift of 5 feet and \$1.20 for a mean lift of 10 feet.

The administration of the business of the district should be placed in the hands of a competent engineer who is familiar with drainage work. He should be held entirely responsible for the proper administration of the district business and especially for the operation and maintenance of the pumping plant. Reliable, skilled attendants should operate the pumping plant under expert supervision and should maintain it in first-class condition the entire year. Full records of the operation of the pumping plant should be kept, as well as detailed classification of expenditures, so that those in charge can determine at all times whether the operation of the plant is as economical as may be possible while securing the results desired from the plant.

Where practicable, gravity outlet sluiceways should be installed in connection with a pumping plant for use during times of low water outside of the drainage district.

The reclamation for agricultural purposes of river bottom lands lying so low that they are subject to serious injury by overflows has been proved by experience in this country and in Europe to be feasible and profitable where the land is of sufficient fertility and where the improvements consist of a system of protective levees supplemented by interior drainage ditches and a suitable pumping plant to remove excessive precipitation which may fall within the district. Such results, however, can come only when the entire plant is properly designed and efficiently maintained and operated.

TABLE 20.—Summary of pumping districts on Illinois River.

Name of district.	Name of officer or landowner.	Address.	Area.		Year of first pump-ing.	Total cost of improve-ments.	Power.		Pumps.		Engines, number and kind.	Boilers.
			Dis-trict.	Water-shed.			Kind.	Horse-power.	No.	Size. ¹		
			<i>Acres.</i>	<i>Acres.</i>						<i>Inches.</i>		
Hennepin.....	Adam Deck.....	Hennepin.....	2,600			\$130,000	Steam.....					
Partridge.....	Eugene Brown.....	Chillicothe.....	3,000	750	1910	45,000	Electric.....	125	1	15		
East Peoria.....		Peoria.....		1,550	1890			135	1	18		
Pekin-La Marsh.....	O. L. Velde.....	Pekin.....	2,000	3,200	1909		do.....		1	12		
Spring Lake.....	J. M. Powers.....	do.....	12,850	22,500	1915	250,000	Steam.....	600	2	26		
Banner-Special.....	W. R. Curran.....	do.....	4,600	8,100	1900	180,000	Electric.....	185	1	24		
Lacey.....	L. S. Turner.....	Havana.....	3,200	3,200	1905	100,000	do.....		2	48		Water tube.
Langellier.....	A. L. Langellier.....	do.....	2,000	2,000	1915	70,000	do.....					
West Mantanzas.....	John H. Wehner.....	do.....	2,700		1909	134,000	do.....	175	1	18		
Otter Creek.....	Warren R. Leach.....	do.....	3,720		1914	107,000	Steam.....	180	1	24		
Big Lake.....	Jesse Lowe.....	Rushville.....	3,270	4,300	1898	155,000	Electric.....	200	2	15		Return tubular.
Coal Creek.....	H. V. Teal.....	Rushville.....	6,700	7,425	1906	353,000	do.....	300	3	20		
Crane Creek.....	W. F. Roegge.....	Meredosia.....	5,340	6,000	1909	125,000	do.....	250	1	36		Do.
Meredosia.....	Wade Ervin.....	Chambers-burg.....	3,760	5,000	1909	135,000	Electric, 1914.....	100				Do.
Magee Creek.....	W. D. Gibbs.....	Winchester.....	11,500	16,500	1913	180,000	do.....	420	2	30		Water tube.
Scott County.....	do.....	do.....	10,500	11,500	1906		do.....	300	3	30		Return tubular.
Big Swan.....	{ Louis L o w e n - stein.	{ White Hall.....	12,000	15,000	1908		{ Electric, 1913.....	100				
Hillview.....	Charles Schutz.....	Hillview.....	12,300	18,500	1910		{ Electric, 1914.....	250	1	32		Scotch marine.
Hartwell.....	W. D. Fairbanks.....	Eldred.....	9,000	10,500	1911		Electric.....	250	2	30		
Fairbanks.....	W. M. White.....	Jerseyville.....	12,000	15,000	1910		Steam.....	450	3	30		300-horsepower return tubular.
Eldred.....	Clarence Reiddish.....	do.....	9,300	9,500	1910		do.....	600	1	36		450-horsepower water tube.
Nutwood.....			10,700	15,000	1911	250,000	do.....	300	1	24		Water tube.
					1910	275,000	do.....	500	3	32		Return tubular.

¹ All pumps of centrifugal type.² Construction.

TABLE 21.—Summary of pumping districts on Mississippi River.

Name of district.	Name of officer or landowner.	Address.	Area.		Year of first pump-ing.	Total cost of improve-ments.	Power.		Pumps.	Engines, number and kind.	Boilers.
			Dis-trict.	Water-shed.			Kind.	Horse-power.			
Drury.....	C. S. H. Young.....	Muscatine, Iowa.....	Acres. 5,000	Acres.	1908	\$20,000	Steam.....	250	1	Comp. cond. Corliss.....	Water tube.
Bay Island.....	M. F. Prouty.....	New Boston, Ill.....	20,000	64,000	1910	242,000	do.....	800	2	do.....	Do.
Muscatine-Louisa.....	Sam. Wilson.....	{Wapello, Iowa. Aleto, Ill.....	{24,000 1,400	94,000	2 1915	281,000	do.....	950	{ 1 2	{ Unflow..... do.....	Water-tube superheat, 125°.
Keithsburg.....	W. J. Graham.....	1,400	1,900	1911	52,000	Oil.....	100	{ 1 1	{ 1 15	{ do..... do.....	Water tube.
Louisa-Des Moines No. 4.	Allen Hall.....	Oakville, Iowa.....	13,000	16,000	1909	108,000	Steam.....	500	2	Comp. cond. Corliss.....	Water tube.
Des Moines County No. 1.	J. H. Pettibone.....	{Burlington, Iowa. do.....	{28,600 17,000	75,000	1911	342,000	do.....	1,230	{ 1 3	{ 2 comp. automatic slide valve. Comp. cond. Corliss.....	Water-tube superheat, 125°.
Henderson County Nos. 1 and 2.	John Ensminger.....	Lima, Ill.....	13,000	22,400	1914	200,000	do.....	600	2	do.....	Water tube.
Lima Lake.....	John Ensminger.....	Lima, Ill.....	13,000	.....	1906	105,000	do.....	400	2	Vertical comp. slide valve.	Return tubular.
Indian Grave.....	J. H. Best.....	Quincy, Ill.....	19,000	.....	3 1914	335,000	.....	.....	.....	.....	.....
Fabius.....	do.....	do.....	16,000	.....	3 1914	400,000	.....	400	2	.....	.....
South Quincy.....	W. P. Martindale.....	do.....	5,500	10,500	2 1915	235,000	Electric.....	400	2	.....	.....
Marion County.....	Ben. Glahn.....	Palmyra, Mo.....	4,000	6,000	1915	135,000	do.....	200	2	Simple Corliss.....	Do.
South River.....	L. C. Hendren.....	Hannibal, Mo.....	9,700	11,200	1911	220,000	Steam.....	200	2	Unflow.....	Water-tube superheat.
Elsberry.....		Elsberry, Mo.....	25,000	25,000	2 1915	480,000	do.....	600	2		

¹ All pumps of centrifugal type² Construction.³ Organized.

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UNITED STATES DEPARTMENT OF AGRICULTURE



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PROFESSIONAL PAPER

November 11, 1915

EXERCISES WITH PLANTS AND ANIMALS FOR SOUTHERN RURAL SCHOOLS.¹

By E. A. MILLER, *Specialist in Agricultural Education.*

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INTRODUCTION.

The purpose of this bulletin is to set forth simple exercises with plants and animals arranged after a monthly sequence plan for the first five grades in southern rural schools. The monthly sequence plan is followed so that plants and animals may be studied at a time when they are most interesting. The monthly exercises provide work for each of the first five grades of the public school. Practical exercises and field trips are suggested. If the best results are to be obtained each pupil should be required to have notebooks and keep records of the observations made and the information secured. In connection with each exercise correlations with other subjects are given. These are intended to be suggestive, but if the idea is followed out and supplemented the ordinary public school branches may be greatly vitalized. It is intended that this publication shall serve as an approach to the study of formal or textbook agriculture in the upper elementary grades.

It is to be understood that this is in no sense a textbook, but a guide for the teacher. There may be communities to which all the exercises given here are not adapted, but in that event they should prove sufficiently suggestive to be helpful to the teacher in planning

¹ Prepared under the direction of C. H. Lane, Chief Specialist in Agricultural Education.

NOTE.— This bulletin is intended especially for the use of rural school teachers in the Southern States.

work that may be substituted. Nothing definite is said concerning the place this work should take in the daily program, but it is suggested that the period of one or two regular classes be used once or twice each week. In other words, it need not be treated as an additional subject in the curriculum but for the sake of its own importance and the vitalizing influence on the other public school subjects this work should be substituted for one or two other recitations each week in the several grades.

All publications referred to in this bulletin may be had free while the supply lasts from the U. S. Department of Agriculture, Washington, D. C.

SEPTEMBER.

(Plate I.)

TO TEACHERS.—The accompanying calendar is a suggestion. One similar to this should occupy a conspicuous place on the blackboard or on a large wall placard. The idea is to have each month some striking feature of nature or of farm life. The calendar may be prepared and decorated by the teacher, or a drawing contest can be conducted with the pupils, awarding to the winner the privilege of making and decorating the calendar.¹

FIRST AND SECOND GRADES.

The work of these grades for the year consists of learning the names of the animals and plants of the community, giving special attention to birds as to where they live, what they eat, and their nesting habits, and to garden flowers and vegetables as to seasons in which they grow. Individual birds and plants are studied.

PLANTS.

Review.—Review the pupils in plants to ascertain what they already know.

Assigned work.—What seeds are being sown in the home or school garden this month—lettuce, radishes? What plants are up and beginning to grow—Irish potatoes, turnips? What plants are in bloom—late corn, okra? What plants maturing or ripening seed—onions, pepper, tomatoes, pole beans? How do these plants grow—on beds, rows? Do the vines or stalks run on the ground, stand erect, or are they supported by frames and poles?

Practical exercises.—Have pupils bring to school roots, leaves, flowers, and seed of garden plants for study. Mount typical specimens of each. (See Farmers' Bul. 586.)

The pupils of this grade should start two or three winter vegetables in the school or home plat. (See planting table in the Appendix.)

Make frequent trips to the school garden to study seed in process of germination and to learn the names of the parts of the plantlets.

¹ The calendar suggestions were furnished by Miss Margaret McAdory, Manual Training Supervisor, Birmingham, Ala.

Correlations.—Correlate the work with language lessons by having the pupils tell orally short stories of their experiences in the garden planting seed, collecting specimens, and observing germinating seed. These short stories should be reduced to writing by pupils of the second grade and the work given a place in the class notebook. (See Pl. II.)

Outlines of leaves, roots, flowers, seeds, and fruits of plants studied should constitute the work in drawing.

ANIMALS.

Review.—Ascertain what the pupils of these grades know about birds and animals. Continue learning the names of animals and birds.

Assigned work.—Specialize in bird studies. List the names of birds that may be seen this month.

Study a few particular birds, such as the blue jay, the humming bird, the mocking bird, the bluebird, and the swallow. Do they reside permanently in your State? Do they migrate south? What do they eat? Where do they build their nests? Is there a reason for the nest being located as it is? What is the color of the head, the breast, the wings, the back, the tail? Do they hop or run, or both? Do they sing—character of note? Imitate.

Practical exercises.—Encourage birds to frequent school and home yards by putting at particular places lunch remnants, meat scraps, and broken grain. Make them “gentle” by feeding and kind treatment. Make trips to the school grounds, fields, and woods to observe the habits of the birds being studied. Make records of observations in the class notebook. The following is an example record:

The Bluebird.

1. Most bluebirds go south in winter. Some remain.
2. They collect most of their food from the ground—insects and weed seeds.
3. They build their nests in hollow stumps, posts, and rails, in gardens, fields, and orchards.
4. There are two special reasons for the location of their nests—to protect their young, and to be convenient to source of food.
5. Color: Head, blue; breast, brown; wings, blue; back, blue; tail, blue.
6. Bluebirds both hop and run.
7. Bluebirds sing.

Correlations.—Ample material abounds for correlation work. Listing birds seen this month, making records of observations, relating stories, oral and written, of experiences on observation trips furnish language lesson exercises. The best written work should have a place in the class notebook.

Make drawings of particular feathers and tracks of each kind of bird studied. The best drawings should be mounted in the class notebook.

THIRD GRADE.

In this grade the population studies in a general way are continued with all plants and animals. More particular studies are made with garden crops. Additional work with annual wild flowers and weeds is undertaken. Particular attention is given individual plants. The bird studies are continued in greater detail, and additional work is undertaken with domestic and economic wild mammals. Lessons with particular animals are outlined.

PLANTS.

Review.—Review the pupils on recognizing at sight trees, flowers, and garden and field crops. This recognition work should be carried further than with the preceding grades. Trips to the forests and fields should be planned for this purpose. Children are easily interested in things that are attractive. Take advantage of this and direct their attention to plants that are attractive in foliage, flowers, or fruit this month. Have pupils make lists of trees, flowers, and garden and field crops they are able to recognize at sight.

Assigned work.—What garden crops are planted this month? Why can they be planted in the fall? Do they continue to grow during the winter months? What garden plants are blooming this month? When were they planted? Why? What garden crops are maturing seeds, roots, or tubers this month? When were they planted or transplanted? Were the plants started in the open or in hotbeds? Why? Will they grow during the winter months? How are their plants reproduced—by seed, roots, or tubers? If left to propagate themselves how would the seed be distributed? Answer these questions with regard to okra, tomatoes, sweet potatoes, and pole beans.

Are there any wild flowers or weeds blooming or ripening seed on the school ground, in the garden, on the roadside, in the pastures, or in the fields? How do they reproduce—by seeds, roots, or underground stems? How are the seeds scattered—attached to clothes of people or skins of animals, by bursting pods, by flying appendages, by birds, or otherwise? Answer these questions with regard to beggar lice, bitterweed, goldenrod, crab grass, milkweed.

List and copy in the class notebook the names of wild flowers and weeds that bloom or mature seed this month. (If you can not learn the names of any that you find, mail them to the State agricultural college with the request that they be identified for you.)

Encourage pupils to have fall and winter garden plats either on the school yard or at home. While caring for the garden plats have them observe seeds in process of germination and learn to name and locate the parts of plants—roots, stems, leaves, flowers, seeds.



BLACKBOARD CALENDAR SUGGESTION FOR A FALL MONTH.



SUGGESTIVE NOTEBOOK COVER.

Practical exercises.—Have pupils select from choice garden plants seeds that are maturing this month. Store seed in small paper bags in a place not subject to extremes of temperature and to the ravages of insects and mice.

Collect roots, stems, leaves, flowers, and seed of blooming and seed-maturing garden plants, wild flowers, and weeds. Mount the leaves and flowers in the class notebook. The roots, stems, and seed should be mounted on separate cards and labeled so as to indicate the name of the plant, the month collected, and the class making the collection. (See Farmers' Bul. 586.)

Correlations.—Language lessons: The trips in search of wild flowers and weeds afford material for written work. The location of a plant, its general appearance, the kind of leaves, flowers, and seed it bears, the manner of distributing its seed should form an outline for a written story.

Drawing: Sketch the roots, stems, leaves, flowers, and fruit or seeds of plants studied this month. The best drawing should be mounted in the class notebook.

ANIMALS.

Review and continued work.—Continue population studies.

Study birds more in detail. Are there new birds to be seen this month? Are they seen in flocks or alone? What do they eat? Do they go farther south or remain for the winter? Begin to look for the bobolink, or rice bird, and the field lark. What member of the class will be the first to report the appearance of a new bird?

Some or all of the following birds will seek a warmer climate during the winter: The cuckoo or rain crow, catbird, martin, kingbird, night and sparrow hawks. They should be given attention before they go away. Compare the males and females. Which are bright? Which dull? Can you give reasons? Uses of feathers on different parts of the body—shedding water, warmth, flying, balancing in air and on perches, propping on trees.

Compare the feathers on the neck, breast, back, wing, and tail of a chicken with those of some other farm fowl—turkey, goose, or guinea. Learn the parts of a feather—quill, barb, and barbel.

New work assigned.—Begin the study of domestic and wild mammals (animals that suckle their young) that are of economic importance this month. What domestic mammals are rendering service? Idle? Gathering their own food? Being fed?

What wild mammals are destroying or damaging garden or field crops? Does the damage done justify their extermination? Are they useful for game?

Answer the following questions with regard to the animals you select for study: Where do they live now? What is the winter home

of each? Do they continue active during the winter or do they hibernate (go into winter quarters)? What do they eat? How do they obtain food?

Practical exercises.—Make trips to study animals and list those studied and record the facts learned in connection with each. Best records should have a place in class notebook.

Correlation.—Language lessons: Write stories on the use of feathers and on the habits of mammals studied this month.

Drawing: Sketch animals studied this month and mount the best ones in class notebook. Find pictures of animals in farm papers and mount in the class notebook.

FOURTH GRADE.

In this grade population studies are continued with plants and animals. The advanced plant studies include field crops and domestic and wild shrubs. The special studies with birds and mammals are continued and additional work with toads and a few common insects is taken up.

PLANTS.

Review and continued work.—Continue the practice in recognizing trees, domestic and wild flowers, garden and field crops. The plants that are especially attractive at this season should be given attention. It is easier to associate names with striking features. Make trips and give reviews often. As new plants are learned add names to the list.

New work assigned.—What field crops are planted this month? Why should they be planted in the fall? Oats? Wheat? Rye? Crimson clover?

What field crops are in bloom this month? When planted and why?

Make a list of all field crops that are planted or that are blooming and maturing seed this month.

Practical exercises.—Select choice seed from field crops and shrubs and store for study or planting. If the seeds are not sufficiently matured to gather, mark them to be gathered at a later date. Seed for identification study should be mounted on cards or placed in screw-capped bottles and labeled.

Gather the matured garden crops, clear away rubbish, and begin preparing soil and planting fall crops. Insist on all pupils of this grade having a garden plat either at home or at school. (See suggested garden crops for this season in Appendix.)

The interior of the schoolroom should be tastily decorated with plants bearing fruit and seed from the gardens and fields. Have pupils bring these to school and assist in decorating. Vitalize the school work by giving the schoolroom an atmosphere of the products of life processes.

Correlations.—Language lessons should consist of stories and descriptions concerning the plants studied, the garden work done, and the fruit and seed collections mounted and stored.

Ample material for drawing lessons is provided by the plants, leaves, fruit, and seed studied this month.

Geography: Simple lessons in distribution of crops may be drawn from such questions as: What crops or parts of crops studied this month are consumed by the family? By the animals and poultry? Are sold for community use? For shipment to other sections? (Blackboard exercise.)

The studies should be correlated with history by simple lessons on the crop under consideration as suggested by the following questions: What plants have been grown in the community a long time? Recently introduced? What shrubs are native? Which introduced? Which have been domesticated a long time? Which recently? (Blackboard exercise.)

Gather data and state problems on cost of production, value, and estimated yields per acre of crops studied this month.

ANIMALS.

Review and continued work.—Birds: Continue the population studies. For advanced work, group the birds you have been studying according to their methods of catching insects. Do they climb over buds, leaves, and limbs looking for insect eggs? Do they search on the ground for cutworms, crickets, and grasshoppers? Do they look among the branches and leaves for caterpillars or do they perch in some open place and dart into the air after flies and beetles?

Mammals: Continue the study of domestic and wild mammals, as indicated in the outline for the third grade.

New work assigned.—The toad is of inestimable value to man in the destruction of harmful insects of garden, orchard, and field. Children should be taught that this homely amphibian is a real friend and that it should be protected in every way possible. The toad will soon go into winter quarters, so the pupils should be encouraged to observe its habits. (Farmers' Bul. 196.)

Some attention should be given to some of the more common insects, such as the boll weevil, the cattle tick, the house fly, the potato beetle, and the white fly. Where common, bring them to school, learn to identify them, become familiar with the injury they work, and note the ways in which they are active during the month.

Practical exercises.—Locate one or more toads in the school yard, home yard, garden, or orchard. Watch closely this month. Is the coat or skin shed? What time of day is the toad moving about? What kind of tongue has the toad? Does the tongue differ from those of other animals in shape? In the way in which it is attached? How is the tongue employed in catching insects? What insects does

the toad eat? Feed it live snails, thousand-legged worms, spiders, grasshoppers, crickets, beetles, cutworms, army worms, tent caterpillars. How does the toad differ from the tree frog? (Farmers' Bul. 196.)

Collect a number of quart bottles with as large mouths as possible. Place in one of these cotton squares with specks on the side that have just been shed, cover with some thin cloth and observe them daily and study the developments. (Farmers' Bul. 512.)

In another bottle place orange or grapefruit leaves that have white dust, small scale-like specks smaller than a pinhead; thick, round-bodied grubs with very short legs and with a bright red spot on the back, or small white flies attached to the under surface. Study developments.

In another bottle place fall Irish potato vines that are infested with beetles. Study daily to become familiar with the various stages of development. Fresh leaves should be added from time to time to furnish food.

Attempt to answer these questions:

- (1) Where do house flies breed?
- (2) How long do they require to develop?
- (3) How many generations are grown in a season?
- (4) How are they dangerous? How prevented?

(Farmers' Bul. 679.)

Mount specimens of insects studied this month. (See Farmers' Bul. 606.)

Correlations.—Language lesson material is abundant. Describing the toad, its habits and means of livelihood and recording observations with the insects studied provide ample subject matter for written work.

Drawings of the toad and the different stages of the insects studied should be made.

Exercises based on estimates of the number of insects destroyed annually by the toad, the number of descendants from one house fly, one boll weevil, one white fly, or one cattle tick in a year, and on estimates of the damage done to the various crops by the descendants of one of these insects in a year provide interesting correlation in arithmetic. (See references for estimates.)

Locate counties freed of cattle tick. Locate on the map the point at which the boll weevil was introduced into this country. Indicate on the map the part of the South infested with the boll weevil.

FIFTH GRADE.

Population studies in plants and animals of all kinds are continued. Advanced studies with orchard and forest trees are taken up. Some more detailed work with mammals and birds is undertaken and special attention is given to economic insects and fungus growths.

Review.—Review the pupils of this grade on the plant population of the community. They should be able to recognize at sight those plants that have been studied by pupils of the lower grades.

New assignment.—Give special attention to orchard and forest trees. Locate and name those that are ripening fruit or maturing seed. Having listed and located the foregoing designated plants, study them to be able to answer the following questions: What are the parts of the trees? In what location—hill, hollow, swamp, ledge of rock—do they flourish? What are the uses of the wood, sap, fruit, seed?

For study throughout the year select a striking tree of economic importance on or near the school yard and begin this month to make observations, take notes, and make drawings along the lines indicated by the following: (1) Outline drawing, accompanied by written description of the tree as it appears this month; (2) outline of a small branch, showing how leaves are attached—long or short stem, opposite or alternate; (3) outlines of leaves, with descriptions to show the relative sizes of leaves from different parts of the tree. Show the color of upper and lower surfaces, the arrangement of veins, and the kind of margin. (The foregoing should be followed throughout the year in the study of the tree selected.)

Practical exercises.—Collecting and mounting leaves, seed, and small specimens of wood of the trees being studied this month and learning to identify them should constitute a part of the practical work. (See Farmers' Bul. 586.)

A large chart should be prepared and placed in a conspicuous place on the wall of the school for recording (phenological) observations. Its purpose should be explained, and the pupils of all grades should be encouraged to assist in gathering data. (For sample chart and explanation see Appendix.)

Every pupil of this grade should have a garden either at school or at home. Gathering vacation crops, clearing away rubbish, preparing and fertilizing the soil, and planting fall and winter crops should occupy the attention of the pupils. Crops should be planted that can be consumed or gathered in time for planting early spring gardens. (For suggested crops see Appendix.)

Correlations.—Language: Write descriptions covering practical exercises with plant studies.

Drawing: Make drawings of the specimens of wood collected. Colored crayons should be used to indicate proper shade of the different parts of the wood.

Geography: Make an outline map of the school district and indicate the locations of orchards and considerable groups of forest trees that have been given special attention this month.

History: Have members of the class prepare statements of the facts as to the kinds of forest and fruit trees that have been and are dying out in the community, and, if possible, state reasons.

Arithmetic: A simple method for determining the number of feet of lumber in a log is: Subtract 4 inches from the diameter of the small end to allow for slab, multiply the remainder by one-half itself, then by the length of the log in feet, and divide by 8.

- (1) Find the number of feet in a log 24 inches in diameter and 16 feet long.
- (2) A tree is cut into three logs each 12 feet long. The diameters for the smaller ends are each 36, 30, and 24 inches. Find the number of feet of lumber in the tree.

ANIMALS.

Review and continued work.—Population studies of all kinds of animals, birds, and insects are continued.

Begin the study of a particular group of birds, say, the woodpeckers or sparrows. Follow this study month by month. Some of the more common woodpeckers are hairy woodpecker, downy woodpecker, flicker or yellow hammer, red-headed woodpecker, and yellow-breasted sapsucker. The following outline is suggested as a guide to group study for the year: (1) General form, size, and appearance of each member of group; (2) color—back, head, throat, breast, tail—both of males and females; (3) methods of each in procuring food and what is eaten; (4) manner of climbing and descending trees; (5) use of beak. What is the drum, and how and when used? (6) Holes—kinds of trees, location, extent, uses; (7) manner of flight; (8) resident or migrant, time of arriving and leaving; (9) places frequented—woods, fields, yards, swamps; (10) kinds of songs, notes, etc.; (11) useful, how? Harmful, how?

Begin a month by month study of a particular group of wild mammals, such as squirrels. The squirrel family includes the gray squirrel, the red squirrel, the ground squirrel or chipmunk, and the woodchuck or "ground hog." The following outline suggests observations and studies for the year with any group of mammals it is convenient to consider:

- (1) General form and size of each animal of the group.
- (2) Color of different parts—head, back, tail, under surface.
- (3) Characteristic parts peculiar to each member of the group or to the group as a whole—teeth, toes, and tail.
- (4) Manner of moving—on ground, climbing and descending.
- (5) Where they make homes—in hollow trees or logs, in burrows, under banks or rubbish.
- (6) What places they frequent—gardens, orchards, fields, woods, barns, and houses.
- (7) What do they eat? Manner of procuring food?
- (8) Do they store a supply of food for winter, go into a dormant or sleeping stage, or gather food in winter?
- (9) Are they useful? How? Harmful? How?
- (10) What are their natural enemies?
- (11) If harmful, how may they be combated? (Yearbook Separate 491, Use of Poisons for Destroying Noxious Mammals, Yearbook 1908, p. 421.)

New assignment.—Give special attention to insect pests and fungus diseases of gardens, orchards, fields, and forests. During this month many of these are especially active making preparations to send a large number of pupæ and spores through the winter months. Insects and fungus diseases that are not recognized should be sent to the State college of agriculture for identification.

Insects found should be studied to learn their life history; that is, appearance of the egg and where deposited, the appearance of the larva and the proper common name to be used for it (grub, caterpillar, or maggot), the length of time spent in that stage, the damage done, and means of destroying; the appearance of the pupa or dormant stage, places in which found, the time spent in this stage, and the methods of destroying; the appearance of the adult and its common name, the places it frequents, the damage done, if any, where it deposits eggs, and methods of destroying.

Have pupils of this grade study and make reports on insects in any stage found during this month in the gardens, orchards, fields, and forests. Parts of plants being attacked should be brought to study the damage done. In the gardens look for cabbage and collard worms, potato beetles; in fields look for the boll weevil, the cotton caterpillar, and the cotton bollworm, the grass or corn worm; in orchards look for the San José scale and the white fly (where citrus fruit is grown); also look for the cattle tick.

The pupils should study and report on fungus diseases. Note the appearance of affected parts, the character of the damage done, and methods of combating. Look for tomato blight, potato blight, potato scab, apple scab, apple black rot, apple bitter rot, sooty mold of citrus fruit and shrubs, fire blight of apple, pear, and quince, cotton boll rot, and corn smut. (See Farmers' Buls. 243 and 440.)

Correlations.—Keeping records of studies with birds, mammals, insects, and fungus diseases and describing the damage done by insects and fungi furnish ample material for written work. Best records and descriptions should be given places in class notebooks. (See Pl. III.)

Drawings should be made showing the different stages of the life history of insects, the damage done to plants attacked by them, and the appearance of fungus diseases on plant parts attacked by them.

These studies may be correlated with geography by making a map of the school district showing the places in which damage is done by insects and fungi. This map should be preserved to be filled in with the results of the studies in the other school months.

Noting the insects and fungi that are native and those that have been introduced, recording the dates of introduction in the case of those that have been introduced, and writing accounts of damage done in each case are suitable for correlation with history.

Problems based on estimates of insects destroyed by different birds studied, and on the damage done by insects and fungi to the garden, field, and fruit crops of the community can be used to supplement the work in arithmetic.

OCTOBER.

FIRST AND SECOND GRADES

PLANTS.

Review the work of September.

Assigned work.—What garden crops are being planted this month—fall radishes, spinach, onions?

- (1) Do you plant radish seed in rows or on a bed?
- (2) What portion of the radish is eaten?
- (3) Do you plant spinach seed in rows, on bed, or broadcast?
- (4) What portion of the plant is eaten?
- (5) From what are fall-planted onions grown—seed, bulb, set?
- (6) Are onions planted in rows, on beds, or both?
- (7) What part of the plant is eaten?

Answer similar questions for other garden crops being planted at this time.

- (1) Are early-planted turnips and fall potatoes ready for use?
- (2) Bring specimens to school if none are in the school garden.

Practical work.—Get some boxes and fill in a thick layer of small stones or cinders, on top of this place a thick layer of loam or leaf mold, on this a layer of clean sand. Set in the sand hyacinth bulbs 3 inches apart each way. Cover the bulbs with a layer of mold, leaving only the tops exposed. Cover with straw or an old sack. Keep in a cool place and water occasionally. After four to six weeks remove the straw or sack, keep in a warm place exposed to morning sun. Water and watch growth.

Continue to care for the school or home garden plats.

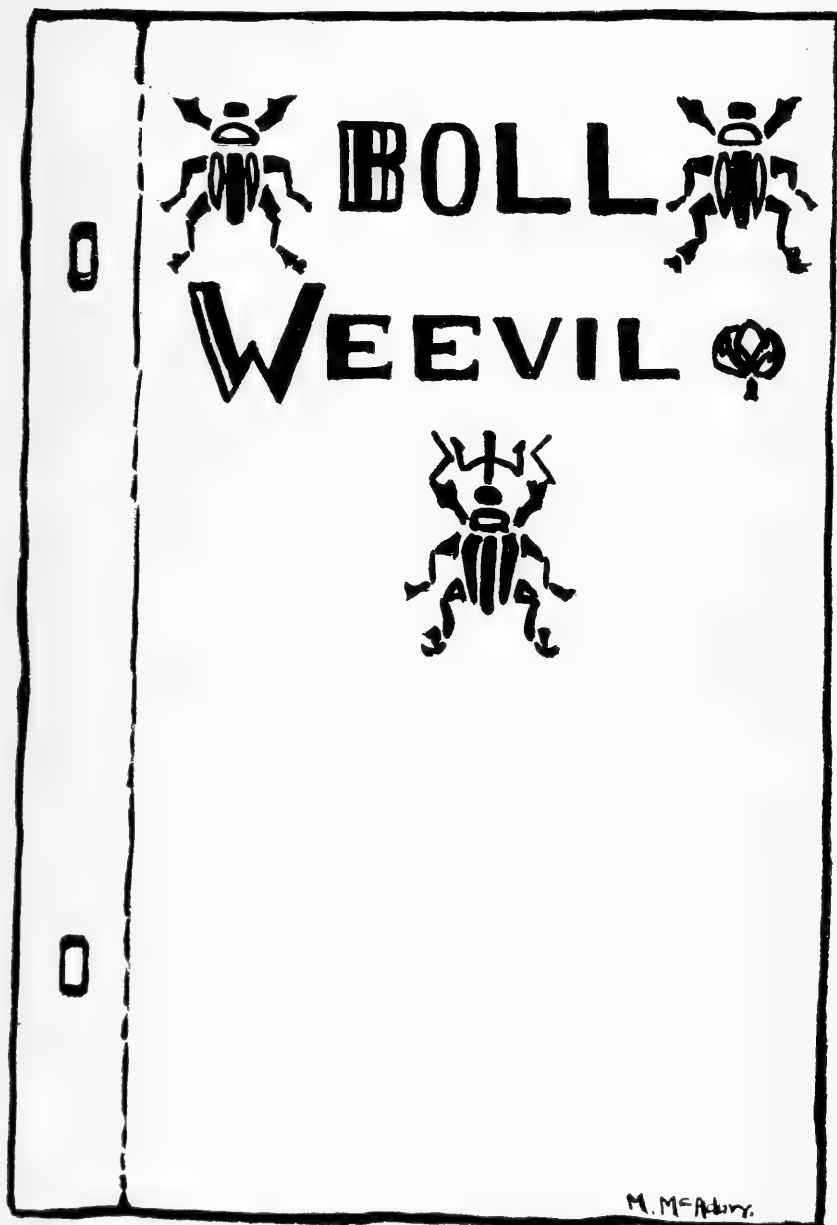
Correlations.—Language: Require pupils to relate the story as to preparing and planting hyacinths; also relate their experiences in their garden plats. These narrations should be reduced to writing.

Drawing: Make drawings of sweet potatoes, Irish potatoes, and turnips. Outline turnip and Irish potato leaves.

ANIMALS.

Review the September bird studies. All of the birds suggested for that month have not migrated yet. Become familiar with their habits before they leave.

Assigned work.—(1) Be on the lookout for new birds—(a) winter residents, those that spend the winter; (b) transients, those that are en route to warmer climate. (2) Note the disappearance of any of the summer residents; some will be leaving the latter part of October.



SUGGESTIVE NOTEBOOK COVER.

(3) The following birds are permanent residents: Flicker or yellow hammer, bobwhite, cardinal or redbird, dove, tufted titmouse, screech owl, wild turkey, American crow, red-eyed vireo, white-breasted nuthatch, house wren, brown thrasher, song sparrow, chipping sparrow, English sparrow, barn owl, red-tailed hawk, blue darter (hawk), killdeer. (4) Select two or three of these for study this month. Follow this outline in studying them and making records:

- (1) What is eaten this month?
- (2) Roosting place?
- (3) Color of parts—head, breast, wings, back, tail?
- (4) Hop, run, or both?
- (5) Character of song—imitate.

Practical work.—Trips to the places frequented by these birds are necessary. Make records of observations as suggested in the foregoing paragraph and copy in the class notebook.

Correlations.—Language lessons are provided by making records of observations. These notes should form the basis of oral narrations.

Drawing: Make sketches of birds studied.

Reading: Read to the class stories of the bobwhite and other birds studied this month, found in Farmers' Buls. 54 and 630.

THIRD GRADE.

PLANTS.

Review the work of the preceding month. If the school term did not begin in September take up as much of the work outlined for that month as is practicable and connect it with the work in October.

Forest trees are putting on gay colors and are dropping nuts this month. Take advantage of those attractive features to familiarize the members of the class with the names of such plants. Note the general appearance of these trees and such particular features as bark, leaves, and nuts. Third-grade pupils should become familiar with the appearance of all field crops that are maturing seed. Are there any members of the class who do not know at sight the plants and seed of corn, cotton, peas, chufas, soy beans, velvet beans, peanuts, and sorghum?

Assigned work.—Have pupils report to class the names of garden crops that are being planted at the homes. Onions? How are such crops planted—in rows, in beds, broadcast? When are such crops expected to be ready for use? What parts—root, stem, seed—are used for food? What parts planted?

What fall garden or truck crops are ready for use or to be harvested this month—Irish potatoes, sweet potatoes, parsnips, others? How and where grown? What parts of the plants are used for food?

Are there any wild flowers or weeds blooming or maturing seed by the roadside or in the field, orchard, pasture, or garden this month? Answer the following questions and record in the class notebook: Name? Where found? Kind of blossom, if any? Appearance of seed? How scattered—by wind, by animals, by birds, by water or by being attached to clothing of people or skins of animals? Which are harmful? Which useful? Keep accurate records of all plants named and studied. Any flowers or weeds you are unable to recognize pack securely and mail to the State college of agriculture with the following letter:

GENTLEMEN:

I am sending to you by this mail securely packed a plant found by pupils of my school. Kindly give us the name, and state whether it is troublesome or useful.

Very truly, yours,

Practical exercises.—Select and mount garden seeds, wild flower and weed seeds maturing this month. (For instructions see Farmers' Bul. 586.)

Plant fall onions in the home or school plats. Care for the young plants in the garden and observe their parts—roots, stems, leaves. (See planting table in Appendix.)

Correlations.—Language lessons: Short written narrations and descriptions are features of practical exercises covering such points as where seeds were found, method of scattering, and general appearance. Garden notes form the basis for short written stories.

Drawing: Make drawings of the wild flowers and wild seeds studied this month. Sketches showing the parts of young garden plants should be made.

ANIMALS.

Review.—Continue the work of learning at sight the names of all kinds of domestic and wild animals and birds. Keep a record of the birds that leave this month. Some few will seek a warmer climate. Be on the alert for the arrival of new birds. These are of two kinds—those on their way south and those that come to spend the winter. Do they travel in flocks or alone? What do they eat? Among the transients look for the ruby-crowned kinglet and the hermit thrush. Among the winter residents look for yellow-bellied sapsucker, downy woodpecker, purple finch, and phoebe. (See Farmers' Buls. 54 and 630.)

Continue the study of the use of feathers on the different parts of the body—shedding water, warmth, flying, balancing in air and on perches, propping on trees.

New work assigned.—The cow is one of the most useful animals and should be given the very best treatment. Study the cow this month to be able to answer the following questions:

- (1) In what way is the cow useful?
- (2) What things does she like to eat?
- (3) How does she get food into her mouth?
- (4) Has the cow upper front teeth?
- (5) What takes the place of the upper front teeth? Cracked pad.
- (6) How does the lower jaw move in chewing?
- (7) Examine the lower front teeth of the cow. Do they seem loose? Can you find a reason?
- (8) Does the cow stop to chew grass as she grazes?
- (9) What is the cow's cud?
- (10) Have cows as many toes as people?
- (11) How many true toes has the cow?
- (12) How many useless toes has the cow?
- (13) How are the toes of the cow protected?
- (14) What means of defense has the cow?
- (15) Does the cow get up on her hind legs or front legs first?
- (16) How do you call your cow? Imitate.

What wild mammals are destroying or damaging garden or field crops this month? Does the damage done justify their extermination? Are they useful for game?

Practical exercises.—Watching for the coming of new birds, recording the disappearance of the summer residents and studying the cow at home with the view of answering the questions suggested in the foregoing outline will keep pupils busy and interested. All facts learned should be recorded in the class notebook.

Correlations.—Language lessons: Ample written work is provided in keeping records for the month.

Drawing: Make drawings of the cow's foot, ear, horn.

FOURTH GRADE.

PLANTS.

Review.—Continue population studies and review the work for September.

New work assigned.—Are any of the farmers of the community planting oats, wheat, rye, or clover this month? How planted—in rows or broadcast? Can the pupils tell why these crops are planted in the fall? What are the uses of these crops? When should they be ready for use, if planted now?

What field crops and domestic and wild shrubs are maturing seed and ripening fruit this month? Corn? Cowpeas? Peanuts? Chufas? Soy beans? Pumpkins? Red haws or "thorn berries?" In case of the field crops, when was each planted? From what part of the plant grown? How planted—in rows or broadcast? How are the different parts of each plant—root, leaves, seed—used? If left alone, how would each kind propagate itself? In case of domestic or wild shrubs, what are the uses of the different parts of the plant? If a domestic plant, how is it propagated—from seed, cuttings, or grafts?

Practical work.—List all plants studied and record the facts indicated in the above questions in class notebook.

Collect seed from the different field crops and mount and label. Seeds or fruits of shrubs should be collected, mounted, and labeled. In case of fruits they should be thoroughly dry before storing or mounting.

Keep the schoolroom decorated with field crops.

Correlations.—Language lessons: Making records of the practical work and descriptions of plants and their uses provide sufficient written work.

Drawing: Make drawings of ears of corn, pea and bean pods, pumpkins, fruits, and seeds of shrubs.

Geography: Have pupils make a product map of the school district. Outline the district as accurately as possible and paste on seed of the different kinds of crops being planted or harvested this month.

Arithmetic:

- (1) Examine an ear of corn of average size. How many rows has it? How many grains per row? How many grains per ear? How many grains in a pint measure? How many grains per bushel?
- (2) Add two more rows to the ear. How many grains would these add? How many such rows would be required to make a bushel?
- (3) By selecting his seed a farmer added 5 grains to each row on the ear. If each ear has 16 rows, how many grains are added to each ear? From how many such ears would this number of grains have to be shelled to fill a pint measure?
- (4) From the foregoing statements develop other exercises.

ANIMALS.

Review and continued work.—Keep up the annual population studies. Before they leave for the winter, classify all the birds that are summer residents according to their manner of catching insects. As new birds arrive observe them carefully and classify them in the same way. The four methods are: (1) Climbing over buds, leaves, and limbs for insect eggs; (2) searching on the ground for cutworms, crickets, and grasshoppers; (3) looking among leaves and branches for caterpillars; and (4) perching in some open place and darting into the air after flies and beetles. Keep records of the work in class notebook.

This is the season of abundant food supply for all kinds of animals. Wild mammals are grouped into three classes according to the manner in which they make provision for the winter: (1) Those that store up nothing for winter, like the rabbit and fox; (2) those that collect a large supply and store it away in a hollow tree or in a burrow, like the chipmunk or ground squirrel; and (3) those that consume a great

deal of food at this time and lay on sufficient fat to enable them to sleep all the winter, like the ground hog.

Study as many of the animals of your community as possible this month and classify them under one of the three heads.

Assigned work.—The ant and the bee are quite similar in some respects. They are making preparations for the winter. In the early part of October attention should be given to these busy little creatures. Valuable lessons can be learned by the pupils from their industry and organized efforts.

The ant community or nest consists of: (1) Workers, which are wingless, and the ones commonly seen; (2) queens, or females, usually one or few at best in a nest and never seen except at mating time (the queen is much larger than the workers). At first they have wings, but after collecting a colony about them they tear their wings off and begin laying eggs; (3) males, smaller than queens, also have wings, but are short-lived and are not seen about the nest except at mating time; and (4) "soldiers," a kind found among some ants which are recognized by their large jaws.

In the latter part of September and the first part of October the young queens and males come out of their nests to mate. Some communities or nests of ants should be located and watched carefully for the purpose of studying the males and queens when they come out.

The workers should be observed to note what preparations they are making for winter in the way of supplying food and arranging their nests. (Reference: Bureau of Entomology Circ. 34.)

The beehive consists of: (1) Workers, the ones usually seen; (2) the queen, one in a hive much larger than the workers, which lays the eggs; and (3) males or drones, smaller than the queens. They mate with the queens in the fall and then die.

Bees should be studied at this time to become familiar with their methods of getting ready for the winter in the way of collecting honey and preparing their hives. (See Farmers' Buls. 442 and 447.)

Practical exercises.—The pupils of the fourth grade must keep their eyes and ears open at home, in the fields, on the way to school, and on the school grounds to learn the things suggested as animal studies this month. The teacher should plan a few trips to the woods and to the home of some one in the community who keeps bees. Let some pupil bring a small bit of honey to school and place at a convenient place outside the building. Watch the bees that visit it.

Correlations.—Making records of the bird and animal groups, and writing stories of the ant and bee provide ample practice in language work.

Drawing: Make drawings of the different kinds of ants and bees.

Geography: Fill in the plant product map of the district with pictures and drawings of the wild mammals studied this month.

Arithmetic:

- (1) Some queens lay as many as 5,000 eggs per day. In how many days can a queen lay a sufficient number of eggs to produce a hive of 20,000 bees?
- (2) One bee can visit on an average of 15 blossoms per minute. How many can it visit an hour? Day?

FIFTH GRADE.

PLANTS.

Continued work.—The pupils of the fifth grade should keep up with the population studies of the various kinds of plants engaged in by the pupils of the lower grades. Have the more advanced pupils form the habit of sending specimens of unknown plants to the State college of agriculture to be named.

New assignment.—Have each pupil make a list of the different varieties of the late fall apples in his or her home orchard and bring to school a few specimens of each. Learn to recognize the fruit of the different varieties. In studying each variety observe the following points: (1) The prevailing size, (2) the characteristic shape, (3) the prevailing color of the skin with the special markings, (4) the thickness of the skin, (5) the flesh of the apple—firmness, color, characteristic taste, and (6) winter keeping qualities. Record in the class notebook the names of all the fall apples grown in the community and the facts learned pertaining to them.

Have the pupils prepare a list of all the domestic and wild plants in the community bearing ripening nuts, such as black and English walnuts, pecans, and different varieties of hickory nuts. Have specimens of each brought to school and learn to recognize them at sight. Study the outside hull—color, thickness, shape; the whole nut—shape, color, density or hardness of shell; kernel—general shape, color, taste. Take notice of location in which each kind or variety of nut prefers to grow. Record all the foregoing facts in the class notebook.

Continue studying the particular tree selected on or near the school yard. (1) Make a new outline showing the general appearance of the tree this month. If the leaves are colored this effect should be given to the outline by use of crayons. (2) Individual leaves should be outlined and properly colored. (3) Drawings should be made showing all the parts of the seed. Written descriptions should accompany the outlines and drawings. This month's study should occupy a place in the class notebook. (Remember that the studies with trees are to be continued through the year and all records for each month should be carefully preserved in a well-bound notebook.)

Practical work.—Collecting material for the foregoing studies affords ample practical work. Specimens of all the different kinds of nuts found in the community should be placed in large bottles with large mouths and labeled for future study.

Correlations.—Language exercises in abundance are afforded in keeping records and writing descriptions of the work outlined for the month.

Drawing: Properly colored drawings of apples, nuts, and parts of nuts should be made. Additional work in drawing is suggested in the study of an individual tree.

Geography: In connection with the geography lesson study the uses of the nut-bearing trees of the community, especially walnut and hickory.

History: If pecans or English walnuts have been introduced into the community, have members of the class prepare statements covering these points: Date introduced, by whom, difficulties met with in their growth and the general success with which they have been grown. If neither of these nuts has been introduced, have members of the class prepare statements covering the history of the devastation of the hickory or walnut timber of the community.

Arithmetic: By counting the number of pecans, walnuts, hickory nuts, etc., in a small measure determine the number in a bushel. Approximate the number produced by some of the trees in the community. Develop exercises on the value of the crops of nuts produced by different kinds of nut-bearing trees in the community.

ANIMALS.

Continued work.—Population studies with all kinds of animals, birds, and insects are continued. This work should be done in connection with the lower classes. The object is to learn to name at sight the animals with which the pupils come into contact.

Continue the studies with a particular group of birds as suggested in the September outline. (For a list of the groups of the more common birds in the South and the individual birds in each group, see Appendix.)

The month by month study of a particular group of wild mammals as suggested in the September outline should be continued.

The insects and fungus diseases studied in September should be continued. The same general suggestions serve for the work of this month.

New assignment.—Take up at this time the study of the grain weevil in corn and the dry rot of sweet potatoes.

Have members of the class bring to school ears of corn and samples of peas attacked by the weevils.

Examine the grains of corn (1) to note the damage done, and (2) to determine the density or firmness of the grains. Are the varieties prolific or large-eared or both? What variety seems most subject to the attack of the weevil? Do the farmers whose corn is attacked by weevils fumigate their cribs with carbon bisulphid?

Have members of the class bring to school sweet potatoes affected with dry rot. Examine them (1) to note the outside appearance, (2) the inside appearance, (3) the odor, and (4) the varieties affected. Are there any varieties not affected?

Seed potatoes should be carefully examined before being stored and then again before being bedded for the purpose of removing all those that are diseased. Dry rot is caused by a germ and the potatoes should be dipped in a formalin solution to kill the germs before being bedded in the spring.

Practical work.—Getting facts with regard to birds, wild mammals, insects, and fungus diseases afford abundant practical work. All facts ascertained should be recorded in the class notebook. Separate books should be used for birds, animals, insects, and fungus diseases.

Specimens of insects should be mounted and preserved for study. (See Farmers' Bul. 606.)

Correlations.—Making records of the class studies and describing insects and fungus diseases and the damages done furnish material for written lessons.

Drawing: Make drawings of weevils in different stages and the appearance of corn attacked by them. Also make drawings of potatoes showing their appearance when affected with dry rot.

Geography: If a robin nests in New York State and spends the winter in Alabama, over what States must he pass in traveling from his summer to his winter home? About how many miles apart are his two homes?

History: Have members of the class prepare a written statement of the loss sustained at each home from dry rot with potatoes. This account should include such points as, when the disease first appeared, the extent to which it has developed, the loss in potatoes each year, and what attempt has been made to prevent it. In case there is no such disease at any of the homes let the account cover the same points with reference to weevils.

Arithmetic: How many bushels of sweet potatoes have been harvested at the homes of the members of the class this month? About how many bushels had dry rot? At the present price of potatoes what is the loss to each home? To the community?

NOVEMBER.

FIRST AND SECOND GRADES.

PLANTS.

Review.—Continue the work suggested for October. Teach the pupils to recognize cone-bearing trees, such as pines, cedars, and spruces.

Assigned work.—Have each of the pupils bring to school a turnip and an Irish potato. There may be several varieties in the collection. First name the different varieties of both turnips and potatoes. Record the names of each in the class notebook with a brief description as to shape, size, and color. This exercise should not be concluded until each pupil can name at sight the different varieties of both the potatoes and turnips.

The next exercise should consist of a comparative study of the potato and turnip. Do both grow in the ground? Are both roots? One is a root and one is a stem. Which is the root and which the stem? Which has eyes? What are eyes? Buds? Do roots have buds? Do stems? What other garden plants resemble turnips? Potatoes? Why are turnips and potatoes so thick and fleshy? Why do people eat turnips and potatoes? Why do not people eat cabbage roots? Lettuce roots? Make a list of all the garden plants known by members of the class that have fleshy roots or underground stems.

Practical exercises.—Refer constantly to the instructions given in the October exercise as to caring for hyacinths. See that they are properly cared for. Studying the development of the young plants should prove interesting work for the members of the class.

Tend carefully the garden plat. If the garden is at home, the pupils should report weekly as to the work they have done, the progress the plants are making, and what disposition is being made of the matured plants.

Correlations.—Language work is provided in recording in the class book facts pertaining to studies of the month.

Drawing: Make drawings of potatoes and turnips. Each variety should be indicated by shape and coloring.

ANIMALS.

Review or continued work.—Continue to look for the arrival of birds that are (a) winter residents and (b) transients. Some transients are on the wing and others spend a little time resting and feeding. Such facts should be noted and recorded. Try to learn the names of all the new ones, both transient and winter residents. (See Farmers' Buls. 54, 456, 497, 506, and 630.)

What summer residents are still to be seen? Make a note of their absence when they disappear.

Assigned work.—For study select two or three additional birds that reside permanently in the community as suggested in the October exercises. Observe them to be able to answer the following questions:

- (1) What are they eating?
- (2) Where do they roost?
- (3) Color of parts—head, neck, breast, wings, back, tail?
- (4) Do they hop, run, or do both?
- (5) How do they fly—slowly, rapidly, undulating, soaring, sailing, flapping?
- (6) Character of song? Imitate.

Learn the names of all fowls at the homes of the pupils. What are little chickens, ducks, geese, and turkeys called? Grown males? Grown females? What does each kind of fowl like to eat?

Keep records in the class notebook.

Practical work.—Much of the pupils' time at home, on the way to and from school, and during rest periods must be consumed in observing the birds along the lines suggested above. Some few excursions to particular fields or woods must be made for observation. Make observations and records as indicated in the following outline:

Flicker or yellow hammer.

- (1) Where is the flicker found this month?
- (2) How can it be told from the field lark—color, flight?
- (3) Describe the color—top of head, back of neck, throat, back, tail, wings, breast. Color and shape of head.
- (4) What does the flicker eat at this season?
- (5) Imitate the sound made by the flicker.
- (6) Locate a conspicuous white spot. When is it seen?

Correlations.—Oral and written sentence making, based on observations with the birds, should be engaged in. Further exercises are furnished in recording facts learned about the birds studied this month.

Drawing: The birds given particular attention should be outlined. Where feathers may be had without injuring the birds, drawings should be made of them.

Reading: See Farmers' Buls. 54 and 630 for selections relating to the birds studied this month.

THIRD GRADE.

PLANTS.

Review or continued work.—With the plant population studies, special attention should be given to cone-bearing trees—pines, cedars, and spruces. Learning to recognize the different plants at sight and

becoming familiar with the cones and leaves should constitute the work. Pupils of this grade should observe the fall crops to be able to distinguish young grains from clovers. They should be able to name at sight the young garden plants. Some specimens of each plant should be brought to the schoolroom for the purpose of familiarizing the pupils with them.

Assigned work.—Before the weeds and wild-flower stalks that are dying down have disappeared, the teacher and pupils should go out with a grubbing hoe and dig up and bring to school the roots of a number of those that have been studied.

Place the roots in two groups—those that are branching and thin in one and those that are thick and fleshy in another. Emphasize the fact that the roots in the first group belong to annual plants and are of no further service, and that those in the second group furnish food for a new growth the following spring. Weeds of the first group are destroyed by preventing their producing seed, and those of the second by keeping the tops and the leaves cut back so that food can not be stored up in the roots or underground stems.

Discard the first lot. Take the second lot and regroup them. Put those that have “eyes” or buds into one group and those that have not into another. Which are true roots? Which underground stems? Look for Johnson grass, poke, Canada thistle, cocklebur, jimson weed, ragweed, crab grass, and ground cherry. (See Farmers’ Bul. 660.)

Practical work.—Carrying out the suggestions above outlined provides practical exercises. Fleshy roots and underground stems should be dried and mounted or stored.

Correlations.—Short written descriptions of the different kinds of roots found provide practice work in language.

Drawing: Abundant material is supplied for drawings. Young field and garden plants and the roots and underground stems found should be outlined.

ANIMALS.

Review and continued work.—Keep up the population studies.

Note and record the names of birds that leave for a warmer climate; also the arrival of new birds. Some are transients and some come to spend the winter. Do they travel in flocks or alone? What do they eat? Do they frequent woods, fields, swamps, orchards, or gardens? Begin to look for wild geese and ducks, red-winged blackbirds, robins, crow-blackbirds, junco or snowbird.

Observations should be continued for the purpose of learning the use of feathers on the different parts of the body—shedding water, warmth, flying, balancing in air or on perches, propping on trees.

New work assigned.—The horse is one of the most faithful animals, and as the cold weather comes on his welfare should be kept in mind.

A warm, well-littered stall should be provided. He should be fed, watered, and brushed with regularity. Study the horse this month to learn the following interesting things about him:

- (1) In what way is the horse useful?
- (2) What does he like to eat?
- (3) How does he get food into his mouth?
- (4) Does the horse chew his food before swallowing?
- (5) How many toes has the horse? One?
- (6) The horse walks on the end of his middle toe.
- (7) The nail has grown all around the end of his toe—what is this called?
- (8) Why does the horse wear iron shoes?
- (9) What is indicated when the horse (1) points his ears forward; (2) backward?
- (10) Can the disposition of the horse be told by the expression of his eye?
- (11) Why are blinders put on horses?
- (12) Which part of the horse lies down first?
- (13) Which part gets up first?
- (14) How do the horse's legs move in walking? Trotting? Pacing? Running?
- (15) What is meant by saying a horse is 15 hands high?
- (16) How does a horse defend or protect himself? Biting, pawing, kicking, running.
- (17) Why does a horse shy? How cured?
- (18) What sounds does a horse make and for what purposes?
- (19) What do you think of a person who leaves his horse standing hitched in in the cold without a blanket?
- (20) Compare the horse and cow as to their feet, manner of eating, and their teeth.

Continue the study with harmful wild mammals. Note the damage done to field, garden, and orchard. In each case when is the damage done—during the day or at night?

Practical work.—Watching for the coming and going of birds, studying the horse with the view of answering the questions outlined, and watching for wild mammals keep the pupils busy. Records of observations should be kept accurately in the notebook.

Correlations.—Keeping records of the month's work and short written stories covering the points outlined for the horse provide ample language work.

Drawing: Drawings should be made of the horse's foot and ear. Outline the horse's body.

FOURTH GRADE.

PLANTS.

Review and continued work.—General population studies are kept up as suggested in the other grades. Review the work assigned for October.

Study the evergreen shrubs found in the yards of the community. Have the pupils bring branches, leaves, and seed to school for study. How are these plants propagated, by cuttings or by seed? Should

cuttings be made this month? Describe the leaves, the bark, the seed. Keep records of facts noted and mount leaves, stems, and seeds.

Study young plants—oats, wheat, rye, and barley. These different stalks may be distinguished by observing the attachments of the leaves to the stems. Does the base of the oat leaf have a clasp? Compare the clasps of the bases of barley, wheat, and rye leaves. Which has the largest? Barley. Which the next—wheat or rye? The clasp of which has small hairs? Wheat.

Practical work.—Providing specimens of the different plants suggested and keeping records of the facts learned with reference to them give abundant practical exercises. Pupils should care for the home or school garden plats and keep the unoccupied ground thoroughly broken or spaded.

Correlations.—Describe the attachments of the leaves of oats, wheat, rye, and barley.

Drawing: Make drawings of evergreen leaves and seeds and of grain plants showing leaf attachments.

Geography: Develop some questions on the uses of oats, wheat, rye, and barley. The following are suggestive: In what different ways are oats fed to stock? Hay? Grain? How is the grain separated from the straw? In what form do oats appear on the table? Some uses of wheat—straw? Grain? Similar questions with rye and barley.

History: Have pupils give a chronological statement of the various steps from the planting of wheat until it appears on the table in the form of bread.

Arithmetic: How many acres of oats, wheat, rye, and barley have been planted this fall at the homes of the pupils of the fourth grade? How many bushels each have been planted at all the homes of the members of the class? How many acres planted in all kinds of grain? If each acre planted in oats should yield 5 bushels more than if planted next spring, what would be the increased yield?

ANIMALS.

Review and continued work.—Classify the new birds as they arrive according to their manner of catching insects. See October exercise for directions. Keep a record of notes in the class book.

Continue the study of wild mammals to learn their methods of making provision for the winter. Many continue to provide winter supplies during this month. See October exercise for suggestions.

Assigned work.—The cottontail is one of the wild mammals that do not hibernate in winter. It feeds on grasses, clovers, vegetables, and other herbs in the spring, summer, and fall, but sometimes it is

necessary for it to eat the green bark of young fruit trees in winter. Study cottontails to be able to answer the following questions:

- (1) What kind of track does the cottontail make? Can you tell which way it is going?
- (2) What time of day does it move about?
- (3) How does it spend the day?
- (4) What are the two most noticeable peculiarities of the rabbit? (Ears, hind legs.)
- (5) How does the rabbit hold its ears—when resting? When startled? When not certain about the direction of the noise? When running?
- (6) How does the rabbit move its head to detect a scent? Observe and explain movements of its nostrils. Note the upper lip, the teeth, whiskers—uses? Eyes—why so placed?
- (7) Compare front and hind legs. How do they differ and why? Front and hind feet.
- (8) Describe the coat. How does the rabbit escape being seen? What is meant by a rabbit “freezing”?
- (9) What kind of nest has the cottontail? What it is it called? Form.
- (10) What are some of the cottontail’s enemies? How does it escape them? Do rabbits fight? How? How do they show anger? With which foot do they stamp?
- (11) What do cottontails eat at this season of the year?
- (12) Let some member of the class capture a cottontail in a box trap and bring it to school in a wire cage for study. Are there white rabbits at any of the homes of the community? Compare the white rabbit and the cottontail.

Spiders are engineers. They build suspension bridges, aeroplanes, and balloons. They are of great value to man since they destroy millions of injurious insects every year, such as flies, mosquitoes, bugs, and grasshoppers. There is not so much danger from their bite as is often thought. Study cobwebs in the school building and in the homes this month to learn the following facts:

- (1) Is the web a sheet or a mass of crisscross tangled threads? How are the threads held in place?
- (2) What is the purpose of the web? Describe the place where the spider hides.
- (3) Entangle a fly or other insect in the web and watch the spider. What does he do with the fly?
- (4) Imprison a spider in a small bottle. Examine carefully to note the number of legs, sections of the body, and pairs of eyes.

Practical work.—Looking for and recording facts concerning new birds and wild mammals, and studying and recording facts with reference to the cottontail and house spider give an abundance of class work.

At least one cottontail and a number of house spiders should be made captive and brought to school. Some member of the class should make a box trap and catch a rabbit for study. He should be put into a small cage made of chicken wire and brought to school. Do not keep him in captivity long. The spiders should be placed in

small bottles and brought to school for study. The web can be studied either at home or at school.

Correlations.—Recording the facts outlined for the study of the rabbit and the spider and writing stories about them give interesting written exercises.

Drawing: Drawings should be made of the cottontail, its ear, front and hind foot. Representations of webs and spiders should be made.

Reading: Have the class read selections from Farmers' Bul. 496.

Geography: Some interesting facts may be brought out by developing questions similar to the following:

- (1) Where does the cottontail make its home or form? (Forest, fields, gardens.)
- (2) What does it eat?
- (3) Does it store up food for winter?
- (4) Is its home or form near to or remote from its source of food supply?
- (5) What relation is there between its color and its safety? Its speed and its safety?
- (6) The cottontail has many enemies and it is very prolific—is there any relation between these two facts?

FIFTH GRADE.

PLANTS.

Continued work.—Practice in recognizing at sight the various plants of the community as they appear this month should be made profitable exercises.

To become proficient in recognizing the different varieties of apples it may be necessary to continue practice in this work. See suggestions in October exercise.

Assigned work.—Special attention should be given to cone-bearing plants—pines, cedars, and spruces. How are these trees alike? Unlike? Compare them as to size, shape, kinds of bark, leaves, cones or seed balls, uses.

Select a striking pine tree and study it according to the following outline:

- (1) Is it like the other pines of the community?
- (2) Kind of bark—ridged or scaly?
- (3) Foliage—where borne, color, number of needles in bundle. Appearance of single needle.
- (4) Cone—kinds, where borne, arrangement of scales.
- (5) Scale—size, shape, location of seed, means of scattering seed.
- (6) How long do pine trees live? Count the rings of a pine stump or the end of a pine cut.
- (7) Uses of pines—wood? Sap?

Continue the studies with the tree selected for the year.

- (1) Make a new outline showing the appearance of the tree at this time. Are the leaves brown? Have some been shed and does the tree look ragged? Have the leaves been shed and is the tree bare?
- (2) What has become of the seeds? How are they scattered?
- (3) Make drawings and write brief descriptions covering the above suggestions.

In the far South special attention should be given to the ripening citrus fruit. Here is abundant material for a month's work comparing oranges, lemons, kumquats, and grapefruit.

Practical work.—Providing apples, bark, leaves, cones, and making observations called for in the foregoing exercises and keeping records in the notebooks furnish practical work.

Look after a school or home garden plat. Care for the crops and keep vacant ground in good condition for early spring crops.

Correlations.—Writing records and descriptions of the plants suggested for study provide language exercises.

Drawing: Outline a pine tree, a cone, a scale, a seed, a bundle of needles, a single needle.

Geography: Have pupils prepare a statement as to the locations of the different cone-bearing plants in the community. Where do the different kinds of pine grow—long-leaf, short-leaf, loblolly? Where do the cedars grow? Spruce, if any? Peculiarities of the various locations should be noted.

History: Have members of the class write statements giving the history of the pine-timber industry in the community for the past 10 years.

Arithmetic: Use the rule given on page 10 to find the number of board feet in logs of various dimensions suggested by pupils.

ANIMALS.

Continued work.—Learn the names of the new birds that come to the community this month. Do any of them belong to the particular group selected for study during the year? Continue the studies with this group. For suggestions see September exercise. (For lists of groups and individuals of each see Appendix.)

These additional facts with reference to the individual members of the group should be noted:

- (1) Appearance—alert, pensive.
- (2) Disposition—social, solitary, wary, unsuspicious.
- (3) Flight—slow, rapid, direct, undulating, soaring, sailing, flapping.

The studies with the particular group of wild mammals is continued. Follow the suggestions in the September exercise.

Which members of the group go into winter quarters? If the squirrel group is being studied, compare the methods of hibernating of the chipmunk or ground squirrel and the woodchuck or ground hog.

Both usually live in the ground and both bore two or more openings to their burrows—one stores up food in its burrow to eat during the winter, and the other gets fat and goes to sleep.

Assigned work.—No insect is of greater economic importance to the southern farmers than the boll weevil. In a very short time it

will have covered the entire area of this section. The best authorities maintain that winter is one of the most important seasons for combating this injurious pest. For these reasons it is very important that the study of insects should include some work with the boll weevil during this month.

(1) Look for the weevil (a) in cracked bolls, (b) in empty burs, (c) under trash and grasses in the field, (d) in cracks in the soil, and (e) in Spanish moss. (2) Does the weevil hibernate in the pupal stage or in the adult state? (3) Does it show evidences of being alive when found? (4) What means of destroying the weevils in such winter quarters suggest themselves—cutting and burning stalks? Raking and burning the rubbish and grass? Breaking the land? (5) Store some weevils in bottles in a cool place. Do they die during the winter? If not, note when they become active in the spring.

Have members of the class find and bring to school potatoes affected with soft rot. Study them after this outline:

- (1) How does affected part appear?
- (2) Can black mold be seen on the potatoes? Is this the cause of the rot? Is this the mold seen on bread?
- (3) What kind of odor do affected potatoes have?
- (4) Have the rotting potatoes bruised or cut places? Should bruised or cut potatoes be stored?
- (5) Are there indications of "sweating" or moisture on other stored potatoes?
- (6) Can soft rot be prevented? How?
- (7) What varieties suffer least? Most?

Practical work.—Searching for boll weevils and potatoes with soft rot and making observations with mammals and birds as suggested give interesting practical work. Boll weevils should be examined and destroyed, and records should be made of all work in notebooks.

Correlations.—The teacher should experience no difficulty in finding ample material for written work.

Drawing: Make drawings of boll weevils, and potatoes affected with soft rot.

History: Read pages 3 and 4, Farmers' Bul. 548.

Arithmetic: If a pair of boll weevils produce a progeny of 10,000,000 individuals in one year, estimate the number that would be prevented if by raking and burning rubbish on an acre of land six hibernating insects should be destroyed. Develop problems for the areas in cotton at the different homes in the class; for the cotton acreage of the community.

DECEMBER.

(Plate IV.)

TO TEACHERS.—The accompanying calendar is a suggestion for the winter months.

FIRST AND SECOND GRADES.

PLANTS.

Review the lesson with potatoes and turnips. Observe the trees. Note their condition at this season and compare with earlier months. Teach the pupils to recognize winter evergreens such as holly, bay, laurel (ivy), mistletoe, and magnolia.

Assigned work.—There should be growing in the school or home gardens spinach, collards, lettuce, and possibly cabbage. If these plants are not found in the school garden one or more specimens of each should be brought to school for study and comparison. If different varieties are grown a sample of each variety should be brought. Direct the attention of the pupils along the following lines: (1) Examine the roots, stems, and leaves. (2) What part of each plant is used as food—roots, stems, leaves? (3) The leaves of which form compact heads—cabbage, collards, lettuce, spinach? Do all varieties of lettuce form heads? (4) How may cabbage be distinguished from collards? From lettuce? (5) How may lettuce be distinguished from spinach? (6) Have the pupils name all the garden plants that they know, the leaves of which are used as food.

Practical work.—Providing the material for the foregoing lessons affords interesting work.

Follow instructions given in the October exercise as to the care of the hyacinths.

Have the members of this grade grow some Chinese sacred narcissus or lily plants to give as Christmas presents to their mothers and friends. Observe the following directions:

- (1) Have each pupil secure a glass dish or crock 3 inches deep and 6 inches in diameter.
- (2) Secure two large bulbs from seed store. Cut away shallowly the hard skin at the top of the bulbs, being careful not to injure the leaf growth.
- (3) Get some coarse pebbles. Put a layer 1 inch deep in the dish. Set bulbs¹ on this layer. Fill in around bulbs with pebbles until dish is filled.
- (4) Put in sufficient water to cover lower half of bulbs. As bulbs continue to grow add more water. After bulbs have grown sufficiently high, fill dish each day with warm water. Pour water in gently on one side and let it flow out on the other side until there has been an entire change of water.
- (5) Keep dish in warm place away from sun for two weeks, then give it abundant sunshine.

¹ Florists often slit the bulbs vertically around the apex as if to quarter, but cut only about one-fourth of an inch deep. This is thought to facilitate flowering.

Correlations.—Language exercises may be provided by relating oral and written stories concerning the vegetables studied and the experiences with flowers.

Drawing: Outlines of cabbage and lettuce heads and leaves, and leaves of collards and spinach should be made. Drawings of the bulbs used should be made.

ANIMALS.

Review and continued work.—Continue the bird studies suggested for November. Take up one or two more of those that reside permanently in the State. Follow the outline suggested in November in making observations. All facts should be recorded in class notebook. Learn the names, uses, and kinds of feed of the farm animals of the community.

Assigned work.—Observe the junco or snowbird and record the facts learned as suggested by the following questions:

- (1) Where is the snowbird seen?
- (2) Does it resemble the sparrow? How?
- (3) Describe as to color—top of head, back of neck, throat, tail, wings, breast.
- (4) What does the snowbird eat this month?
- (5) Can you imitate its sounds?

Practical work.—Spend as much time as the weather conditions will permit obtaining information called for in the studies.

Correlations.—Oral discussions and making records furnish ample language work.

Drawings: Sketch the birds that have been given special attention. Where feathers may be had without injury to birds drawings should be made of those taken from the different parts of the body.

Reading: Selections from Farmers' Bul. 630 should be read to the class.

THIRD GRADE.

PLANTS.

Review and continued work.—Population studies should be continued especially with domestic and wild evergreen shrubs and trees. Have the pupils bring to school branches of plants being studied.

Assigned work.—During this month the time of the pupils of this grade may be profitably spent studying and comparing the weed seeds collected and mounted in the fall. Use the following suggestions as a guide in learning to recognize the different weed and wild flower seeds: Note (1) the size, (2) the shape, (3) the color, (4) the kind of seed covering, and (5) special parts for use in disseminating the seeds by wind, water, and animals.

Practical work.—The work out of class should consist of locating and bringing to school branches of the evergreens being studied. Notes should be made as to the locations at which these plants are found.

Correlations.—Brief written descriptions of the weed and wild flower seeds being studied and classified should be made.

Drawing: Ample work in drawing is provided in outlining and coloring the seeds.

ANIMALS.

Review and continued work.—So far as weather conditions permit keep up population studies with birds and animals.

Look for new birds and study them after the outline suggested for previous months.

New work assigned.—The pig is one of the most important sources of animal food. A large number of them are butchered during this month; hence it is opportune to study this valuable farm animal. The following suggestions are given as a guide in making investigations:

- (1) How does the pig's nose differ from that of any other animal? Uses—smelling, rooting.
- (2) How do hogs fight or defend themselves? Describe the fighting teeth.
- (3) Do hogs see well?
- (4) What shapes are the heads of hogs—wedge? Dish-faced? Do the ears stand out straight or are they lopped? Is the wedge-shaped head an advantage to the wild hog?
- (5) Observe the pig's hair. Is it thick enough to keep off flies? Why do hogs wallow in the mud? Are they naturally filthy? Do they attempt to clean themselves? When do the hog's bristles stand up?
- (6) What does the hog like to eat?
- (7) How many toes has the pig—true? False? Of what use are the false toes? Can the pig run fast?
- (8) What uses has the pig's tail?
- (9) What cries and noises does the pig make that are understood—hunger? Satisfaction? Anger? Fear? Others?
- (10) Mention instances to show the hog's intelligence.

Practical work.—Practical work is provided in observing hogs and the damage done by wild mammals and making records of the facts learned. Many important facts about hogs may be learned while they are being dressed.

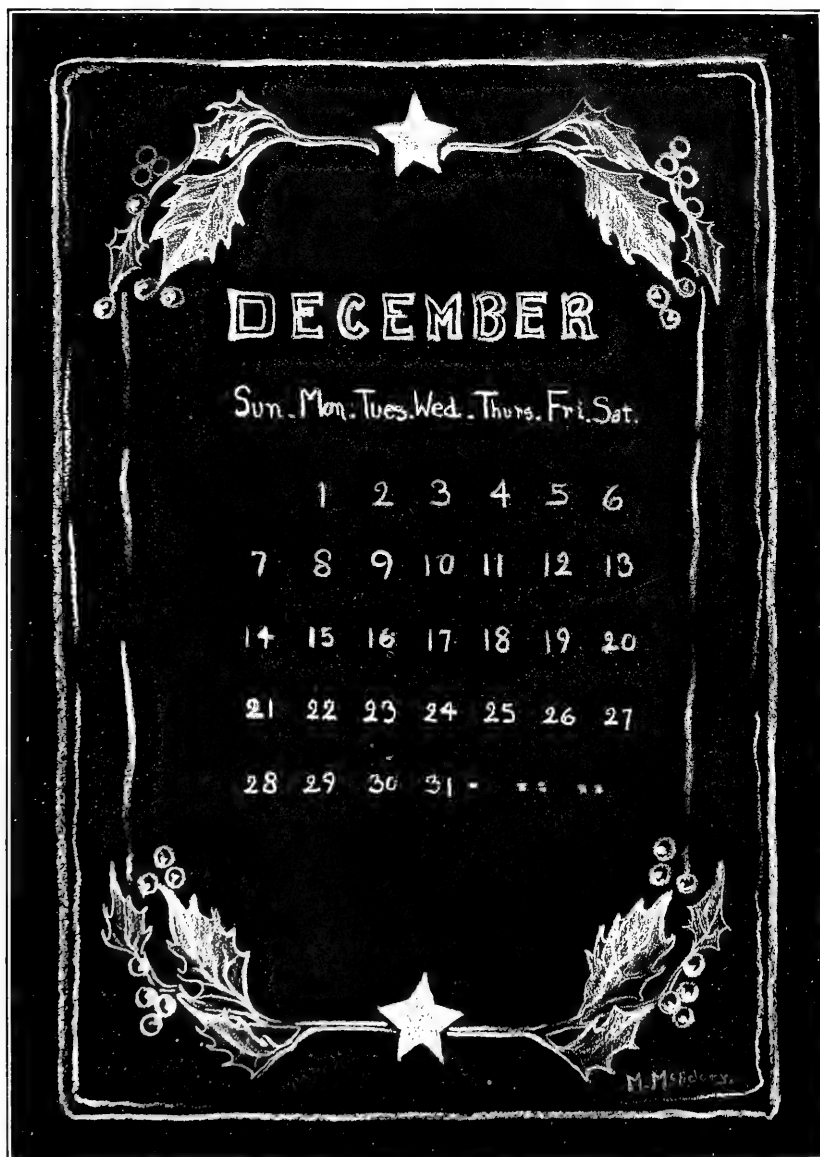
Correlations.—Have members of the class tell short stories orally and in writing concerning their observations with hogs.

Drawing: Make outline drawings of the hog showing wedge-shaped heads and dished faces.

FOURTH GRADE.

PLANTS.

Review and continued work.—The pupils of this grade should give special attention to the laurel (sometimes called poison ivy) this month. It is of considerable economic importance since its leaves contain a very active poison. Owing to its being green at a season when most plants are not, stock running in pastures or open woods



BLACKBOARD CALENDAR SUGGESTIONS.

where it is found are attracted to it. Pupils should be taught to recognize the plant and remove it from pastures. The following questions suggest an outline of study: (1) Where does the laurel grow? (2) What kind of soil does it like? (3) How tall do the plants usually grow? (4) What is the shape of the leaves? The shade of green? (5) What other plant leaves are similar?

Assigned work.—The pupils of this grade should learn to prepare and “heel-in” cuttings.

- (1) What is a cutting? Use?
- (2) Of what part of the plant are cuttings made? Last season’s growth.
- (3) Name some plants grown from cuttings—grape, gooseberry, willows, poplars.
- (4) How long should the cutting be? How many buds should it contain—one, two, or more?
- (5) Should the cuts be made near the buds or at some distance above and below?
- (6) What is the bud at the lower end for? The upper end?
- (7) Should cuttings be planted in December?
- (8) What should be done with them until planting time? Tied in bundles and buried in trench, bottom end up.

(See Farmers’ Bul. 157, pp. 10, 11, and 12.)

Practical work.—Secure laurel branches for schoolroom study. Have pupils bring from their homes grapevine prunings to be used in making cuttings. Make cuttings from healthy last year’s growth. Use sharp knife. Let each cutting have a bud near top and near base and be about 10 to 12 inches long. Tie in bundles and bury bottom end up in a trench in some corner of the school ground. Does the scuppernong grape root readily from cuttings? They may be readily propagated by “layers.” What is a “layer”?

Correlations.—Language lessons are provided by brief written descriptions of the laurel and written accounts of the steps taken in preparing grape cuttings and layers.

Drawing: Require the class to make drawings of laurel leaves—attached to the branch and detached; also outlines of ideal and improper cuttings.

Geography: Develop questions as to the locations in which laurel and grapes prefer to grow. Compare these locations, showing in what respects they are alike or unlike. What lesson may be drawn from this study with reference to there being a place for everything and (if left undisturbed) everything in its place?

History: Have each pupil who brings a grapevine to the school report the name of the particular variety. Let questions be developed to show the date of introduction into the community, the uses and the relative merits of the different varieties.

Arithmetic: Have pupils of the class report the number of grapevines at their homes. Find the total number of vines and estimate the yield for each vine and the total yield in pounds or gallons (in case of scuppernong) of all vines reported.

ANIMALS.

Review and continued work.—Continue the study of birds. Watch those of the different groups classified according to their manner of catching insects, and note what the members of each group are eating. Do some of them continue to look for insects and insect eggs in the crevices of bark and under bud scales? Encourage the birds to visit school grounds by placing lunch remnants, broken grain, scraps of meat and suet at places convenient for them and out of reach of cats.

Continue the study of wild mammals that provide their food during the winter months. What are rabbits, rats, opossums, and squirrels eating this month? Where do they get their food? At what time do they go forth in search of food?

Offer some reward to the member of the class that first finds a woodchuck or groundhog burrow. Visit the burrow with the class to become familiar with the home conditions of this interesting mammal.

Employ the following outline in a study of the house mouse this month:

- (1) What is the color of the mouse? Is the color an advantage?
- (2) What is the nature of the coat of the mouse?
- (3) The tail—length compared with that of the body; its use?
- (4) Compare the front and hind limbs; front and hind feet. Can it climb the side of a wall? How?
- (5) Can the mouse see well? Hear well? Smell well?
- (6) What are the uses of the teeth? The whiskers? What kind of teeth has the mouse?
- (7) What kind of food does the mouse eat? How does he get it? Steal?
- (8) Where does the mouse make its home? Of what material? How do baby mice appear? Can they see when quite young?
- (9) Mice are great travelers. How do they get from place to place?
- (10) How many kinds of mice do you know?

Practical work.—Make observations with birds and mammals as suggested above. Make a trip to the home of a groundhog. Study it and take notes. Capture a mouse, imprison it in a large-mouthed bottle and study it as suggested in the outline. Keep records of all observations and facts learned.

Correlations.—Write stories about the home of the woodchuck and the habits of the mouse.

Geography: Compare the homes of the woodchuck and the house mouse as to location.

History: Read "Introduction," Farmers' Buls. 369, How to Destroy Rats, and 670, Field Mice as Farm and Orchard Pests.

FIFTH GRADE.

PLANTS.

Continued work.—Noting the appearance of familiar trees at this season and comparing their appearance with that of former months furnish interesting and instructive observation exercises.

Review the work with cone-bearing plants. Their peculiar method of bearing seed and their great usefulness make them an important group.

Continue the studies with the special tree selected for attention this year. (1) Make an outline showing its appearance this month. (2) Have the leaves been shed? (3) Where were the seeds-borne the past season? (4) How have they been scattered? (5) How are the seed naturally protected from the cold?

New work assigned.—Give special attention to other evergreens, such as holly, bay, magnolia, laurel, mistletoe. Compare the bay and magnolia as to (1) general appearance, (2) character of bark, (3) shape, size, and color of under surfaces of leaves. (4) Do they appear to be related? Note the peculiarities of the holly—the leaves and the fruit. The leaves of the holly have spines and the leaves of the laurel contain poison. Of what value are these to the plants? Can animals eat holly leaves? What is the result if animals eat laurel leaves? Study the leaves, fruit, source of food of the mistletoe. Is this plant found on living, dead, or dying trees? It is called a parasite. Why?

Study the holly after the following outline: (1) Where in the neighborhood does the holly grow? (2) What is its general shape? (3) How tall does it grow? (4) What are the size, shape, and peculiarities of the leaves? (5) Does the holly shed its leaves? (6) Where are the seeds borne? (7) How are the seeds scattered? (8) Do animals or birds eat holly seeds? (9) What are the uses of the holly plant? (10) At what season is it used for decorative purposes? Why is it so highly valued for this purpose?

Practical work.—Ample practical work is provided for in making observations and securing material for study as called for in the foregoing suggestions. Make cuttings of willow twigs and store in boxes of sand and keep in cool place. Have vacant garden plats well spaded. Keep clean and in condition for early spring vegetables. Get materials together to make a hotbed for forcing early spring vegetables. (See Farmers' Buls. 255 and 647.)

Correlations.—The material for language work is abundant. Make records of the studies outlined and develop written accounts from these facts.

Drawing: Make drawings of the leaves and seeds of plants studied. Make a sketch of the hotbed.

Geography: Have the pupils prepare a statement giving the particular locations in the community at which the several plants studied grow. These statements should include the points characteristic of each locality—along streams, on lowlands, uplands, or ledges.

Arithmetic: Develop problems on the sizes of hotbeds necessary to furnish given numbers of plants.

ANIMALS.

Continued work.—Continue the studies with birds as outlined for the previous months. How the members of the bird group get their food, what they eat, and what places they frequent should constitute the principal points for consideration.

Some members of the squirrel group have gone into winter quarters. It is advisable to take up some one member of the group and devote special attention to it this month.

The following suggestive outline is offered for the study of the gray squirrel:

- (1) Where does the gray squirrel make its home?
- (2) Does it run or hop?
- (3) How does it go up a tree? Down?
- (4) How does it pass from tree to tree?
- (5) How does it hold its legs and tail while jumping from tree to tree?
- (6) Describe the colors of the gray squirrel above and below.
- (7) Do the squirrel's colors protect it from its enemies?
- (8) Locate and describe the squirrel's eyes? Are its legs long or short? Why? Compare fore legs and hind legs.
- (9) Describe and give uses of the tail.
- (10) What does the squirrel eat in winter? Where stored? How does it carry its food?
- (11) How does the squirrel express excitement, surprise, anger, joy? Note its sounds.
- (12) How does the squirrel get the kernel out of a nut?
- (13) How are its teeth arranged to gnaw holes in such hard substances?
- (14) Are squirrels of any use to man?
- (15) What damage is done by squirrels?

Assigned work.—Have some member of the class bring to school branches of fruit trees—apple, peach, etc., known to be affected with San José (San Hosay) scale. Use magnifying glass to show both the scale and the insect body beneath it. Examine closely to become familiar with the general appearance of affected parts. Study the effect of this scale upon the manner of growth and general appearance of a peach tree. What parts are killed first? Why? Impress the following facts upon the pupils:

- (1) The San José scale is an insect.
- (2) Its body is protected by a scale covering.
- (3) To the naked eye the scale consists of light and dark gray rings with dark spot in the center.
- (4) Where abundant, scales give an ashy-gray appearance to the bark of the affected part.
- (5) It is one of the most injurious orchard pests.
- (6) During the winter months is the time to combat the pest, and lime-sulphur wash is the best spray.
- (7) Every farm boy and girl should be able to recognize it.
- (8) Burn affected parts after examination.

Practical work.—Trips to observe birds and squirrels are necessary. After members of the class have become familiar with the appearance of parts of fruit trees affected with San José scale trips should be made by the class to neighborhood orchards for the purpose of detecting the presence of the pest.

Correlations.—Written exercises on the squirrel and description of plants and parts affected with San José scale furnish language lesson work.

Drawing: Sketches of the squirrel and parts of plants affected with the scale should be made.

Geography: Have pupils of this grade prepare an outline map of the school district and indicate thereon the locations of orchards affected with San José scale.

History: Have pupils prepare written accounts covering the data of introduction, the spread and the damage done by the San José scale in the community.

Arithmetic: Have pupils report to class the number of fruit trees at their homes that have been destroyed by the scale. Develop exercises in arithmetic as to the loss sustained by the community in this way.

JANUARY.

FIRST AND SECOND GRADES.

PLANTS.

Continued work.—Studies with spinach, collards, lettuce, and cabbage should be continued. If young plants can not be obtained in the school or home garden a few seeds of each should be planted in a cigar or crayon box and some specimen plants grown for the class to study. Review the work with evergreen trees. Practice the pupils in recognizing orchard and forest trees that are bare.

Assigned work.—Under the direction of the teacher let the pupils of this grade start a window box. Observe the following directions:

1. Secure or make a box 7 inches deep, 8 to 10 inches wide, and as long as the window is wide.

2. Bore several small holes in the bottom of the box, place over these broken pottery, hollow side down, then a half-inch layer of pebbles or small stones, and cover these with an inch layer of leaf mold or fine trashy material.

3. Fill with soil consisting of one part thoroughly pulverized manure, one part garden soil, and one part sand.

4. Water thoroughly and let stand for two or three days, and add more soil if it settles.

5. When the soil becomes mellow so that it falls apart when compressed lightly within the hand it is in the right condition for planting the seed.

6. Make slight depressions with the edge of a straight board. Sow any of the following kinds of seeds: Petunias, begonias, pansies, sweet alyssum, and geraniums. If a variety is desired, sow two or more kinds.

7. Water frequently in the late afternoon and keep box indoors when the weather is very cold.

Hanging baskets may be provided in the same general way. One or more of the following plants with drooping habits may be planted: Variegated periwinkle, trailing fuchsia, wandering Jew, and oxalis.

Practical work.—Ample practical work is provided in securing boxes, preparing soil, planting seed, and watering and caring for the plants.

Correlations.—Language: Talk about the work. Write names of equipment and flowers on blackboard.

Drawing: Make a sketch of the window box.

ANIMALS.

Continued work.—Have pupils collect scraps of meat, mixed grain, and luncheon remnants for the birds. Place these in convenient places about the school yard. Study the birds that visit the grounds this month. Continue the studies with farm animals.

Assigned work.—The cardinal or redbird furnishes an interesting topic for study. The following questions suggest an outline for study:

- (1) Where is the redbird seen most frequently?
- (2) How do the males and females differ in color?
- (3) Describe the color of each—head, neck, back, breast, wings, tail.
- (4) What does the redbird eat this month?
- (5) Imitate its song.

Practical work.—Make observations with a view to answering the questions in the foregoing studies. Find an old redbird nest and bring to school for study.

Correlations.—Language: Have pupils copy in their notebooks a record of the observations with the redbird.

THIRD GRADE.

PLANTS.

Continued work.—The practice in recognizing weed seeds should be continued as suggested for December.

Assigned work.—Cooperate with the second grade pupils in preparing window boxes. Pupils of this grade should arouse the interest of the parents in such work at their homes.

Practical work.—This is provided in making window boxes, mixing the soil, sowing seed, and caring for the plants.

Begin preparing the soil in the school and home gardens for the early spring planting. Apply manure broadcast. Spade or plow the soil thoroughly and make lists or beds for the seed or young plants.

Lettuce and cabbage plants should be started in the hotbed or in a box kept indoors. For the indoor box use a soil mixture similar to that used for a window box.

Correlations.—Language: Have pupils copy in class notebooks directions for making window boxes. See second grade work.

Drawing: Outline window box. Make drawings of seed.

ANIMALS.

Continued work.—Make a list of all birds seen in the community this month. They consist of two kinds, namely, permanent residents and winter residents. This list should be made as complete as possible. Compare with the list made in September. What birds are missing? What birds are found that were present in September? What new birds are found that are not in the September list? What birds were seen in October, November, and December that were not seen in September and that are not found now? Classify these groups under the following heads: Summer residents, transients, winter residents, and permanent residents.

Assigned work.—The dog is the first animal domesticated by man. In many ways he has proved a faithful friend and valuable helper to his adopted master. The fact that the dog in his undomesticated state had social instincts accounts for the ease with which he was domesticated. As a wolf the dog lived in a pack and when domesticated he readily transferred allegiance from the pack leader to his new master. Study the dog carefully this month to learn the following facts:

- (1) How many useful toes has the dog in his front foot? How many useless?
- (2) How many of each on the hind foot?
- (3) Locate the dog's wrist, elbow, shoulder.
- (4) Locate the dog's heel, knee, hip.
- (5) Teeth—front or incisors, like a wedge; canine or dog teeth, long and sharp for seizing and holding prey; molars or jaw teeth, like scissors for chopping meat. Compare the dog's teeth with those of the horse.
- (6) How does the dog lie down?
- (7) The dog barks at his enemy or prey. Why?
- (8) How is the dog enabled to follow his prey? Examine the tip of the dog's nose.
- (9) Name the kinds of dogs that like to hunt; that care for flocks and herds of animals; that watch or guard premises.
- (10) How do the dogs make a desirable companion or playfellow? What tricks may be taught to a dog?
- (11) What makes dogs fat, lazy, and stupid?
- (12) Should a grown dog be fed more than once a day? What kinds of food do dogs like? How does a dog drink?

Practical work.—Listing birds and studying dogs provide ample work. All facts should be recorded in the class notebook.

Correlations.—Language: Making records called for in practical work provides sufficient written work.

Drawing: Make a sketch of a dog. Have each pupil make a sketch of the ear of his dog. Compare the drawings.

FOURTH GRADE.

PLANTS.

Continued work.—From the class notebook get a list of the domestic and wild shrubs that have been studied by the class in previous months. Examine them in their bare state and compare them with appearances when studied before.

Assigned work.—The pupils in the fourth and fifth grades should plant seeds in the hotbed to start plants for the pupils of the first five grades. Cabbage, lettuce, eggplants, and pepper seeds should be planted in the hotbed this month. Shallots and cabbage plants started in the fall should be set out this month.

Have the pupils of the fourth and fifth grades prepare the ground and sow some sweet peas. Observe these directions:

1. Select the border of the school garden or yard.
2. Spade the soil to a depth of 10 or 12 inches and loosen up the subsoil several inches.
3. Mix the soil with 3 or 4 inches of well-rotted manure.
4. Sow the seeds an inch apart in single rows. Cover 1 inch and press the ground down firmly.
5. When plants are well out of the ground thin to 3 inches apart.
6. When plants begin to run support them with brush or stakes about 4 feet high.
7. Keep soil loose and free of weeds. If soil becomes dry, water freely.
8. Cut flowers frequently to prolong the blossoming period.

Practical work.—Making observations with shrubs, seeding hotbeds, planting school gardens, preparing the soil and planting sweet peas give ample work.

Correlations.—Language: Have pupils prepare a written account covering the steps in planting sweet peas.

ANIMALS.

Continued work.—The birds to be seen this month are either permanent or winter residents. The permanent residents have been placed in one of the four groups in previous months. The winter residents should be closely observed and classified. Answer the following questions:

- (1) Of what does the bird's clothing consist?
- (2) How are the feathers arranged on a hen's back? Breast? Neck? Have a hen brought to the class for study.
- (3) Compare a feather from the back and from the breast.
- (4) Are both ends of feathers alike? How do they differ and why?
- (5) Are some feathers all fluff or down?
- (6) At what age are the feathers of a bird or chicken all down? How protected from the weather at this age?
- (7) What is a pin feather?
- (8) How does the hen oil her feathers? Where does she get the oil? Why does she oil her feathers? Have you seen a hen or bird oiling its feathers?

What are the wild mammals doing this month? Rabbits? Squirrels? House mice? How do they protect themselves from the cold? What do they eat? What damage, if any, is being done by any of them?

Assigned work.—Collect cocoons found on oaks, hickories, and cedars. Cut some open and note the state of the insect. This is the pupa, dormant or sleeping stage. Preserve some cocoons in a bottle to note the emergence of moths in spring. Give plenty of room and have twigs in the bottle for moths to alight on. (See Farmers' Bul. 606.)

Practical work.—Make the observations and collections provided for in the preceding work and make notes in the class booklet. Ask the girls in the class to provide bottles, and the boys to collect the cocoons.

Correlations.—Language: Describe the cocoons and the appearance of the insects at this stage.

Drawing: Make sketches of feathers from the different parts of the body of the hen; of the cocoon and of the insect in the pupa stage.

Geography: Why do birds go farther south in winter, for food or for a warmer climate? What impression with reference to this question is to be had from studying the winter residents of the community?

History: Have members of the class relate superstitions concerning the screech owl. Let the teacher take occasion to decry these fallacies.

FIFTH GRADE.

PLANTS.

Continued work.—Review the studies with evergreens as outlined for December.

Continue the studies with the special tree selected at the beginning of the year. Make an outline drawing of the tree accompanied by a written description. Collect specimens of the bark. Study it and compare it with bark of related trees and those not related. Compare the drawings of the tree for the previous months with that of January.

New work assigned.—During this month the time of the pupils may be profitably spent comparing the seeds of different forest and fruit trees. These should have been collected in October and November and stored or mounted for use at this time. Note: (1) The shape, (2) the color, (3) the character of coats or cases, and (4) the kernel of the different seeds. Special attention should be given to the different kinds of acorns, chestnuts, hickory nuts, walnuts, and peach stones; also orange, grapefruit, and lemon seeds.

Practical work.—Making notes of observations in connection with the particular tree being studied and the different nuts, and copying these notes in the class notebook furnish practical work. The pupils of this grade should cooperate with those of the fourth grade in seedling hotbeds. Some early vegetables should be planted in the open. (See planting table.)

Correlations.—Language: Have members of the class write a description of one or more seeds studied, covering the points given as in the outline.

Drawing: Make drawings of the seeds and nuts studied.

ANIMALS.

Continued work.—The studies with the group of birds selected for the year should be continued. Have any members of this group gone farther south? Have others come from farther north? How are they securing their food? What are they eating? What places do they frequent?

The group of mammals selected for study throughout the year should be given attention. How do they protect themselves from the cold? What do they eat? How do they compare in these respects with other wild mammals? Compare the gray squirrel and the rabbit?

Assigned work.—The transverse borers resemble very much cotton boll weevils. They should be studied for this reason. Examine the roots of cocklebur and ragweed for this insect. Gather the roots of a number of these plants, split them open and look for the insects.

Locate and learn to identify shot-hole borers. These are found in both the outer and inner bark of peach, plum, and apple tree trunks and limbs. Their presence is indicated by small holes and gum exudation on peaches and plums. The larvæ of this insect may be removed by digging into the bark with a sharp knife at the point where the hole or gum appears.

Practical work.—Make observations and take notes on birds and mammals as suggested. Further practical work is provided in searching for and learning to identify transverse borers and shot-hole borers. Specimens of these should be preserved. (See Farmers' Bul. 606.)

Correlations.—Language and drawing: Write descriptions and make drawings of transverse and shot-hole borers.

FEBRUARY.

FIRST AND SECOND GRADES.

PLANTS.

Continued work.—Care for the window and porch boxes as suggested in the January exercise. Begin the outdoor garden work. Each pupil should have a plat either at home or at school. (See planting table in the Appendix.)

Assigned work.—Start plants in the open garden. Onion sets, radishes, lettuce, and spinach are among the garden plants that the pupils of this grade should get started this month. Such questions as the following should be asked by the teacher with reference to each plant:

- (1) How planted, in rows, on beds, or broadcast?
- (2) How far apart should rows be?
- (3) How far apart should plants stand in rows? On beds?
- (4) What quantity of seed is required to plant a 100-foot row?
- (5) To what depth should seed be planted?
- (6) When should the plants be ready for the table?

Sweet Williams, pansies, sweet violets, white verbenas, petunias, and zinnias are among the flowers from which selections may be made for beds and borders. The soil should be prepared and fertilized and the seed planted this month or the early part of March.

Practical work.—Caring for the window and porch boxes and preparing the soil, adding fertilizers and sowing vegetable and flower seeds provide ample practical work.

Correlations.—Language: Have pupils keep notes of their garden experiences such as kinds of seeds planted, date of planting, amount of fertilizer and such items.

Drawing: Make an outline sketch of the individual plat, also of the boards that are to be used to indicate the location of different kinds of vegetables and flowers.

ANIMALS.

Continued work.—Continue feeding birds and learning to recognize them. Be on the lookout for transients on their way back north. Note the dates on which they are seen and the manner of their flight. Do they pass on without stopping or do they tarry some time in the community? Look for the following: Wild geese, wild ducks, hermit thrush, and bobolink. Study the dog with the class, using the following outline: (1) Kind of dog at each pupil's home. (2) Name the different kinds of dogs in the community. (3) How does the dog express friendliness? Affection? Anger? Fear? Shame? Attention? (4) What should the dogs be fed? (5) What should be done to make dogs comfortable? (6) In what ways are dogs useful? Harmful?

Assigned work.—Among the woodpeckers the red-bellied woodpecker is one of the most interesting for special study. Employ the following outline in studying this or some other member of the woodpecker group:

- (1) Where seen most frequently?
- (2) How do the males and females differ in color?
- (3) Describe the color of head, neck, back, breast, wings, and tail of each.
- (4) What does the woodpecker eat this month?
- (5) How does it obtain its food?
- (6) Imitate its song or cry.

Practical work.—Making excursions to study and take notes on birds furnishes ample practice work. Pupils should make observations at home, on the way to and from school, and at school. These observations should be briefly noted.

Correlations.—Language: Record in the class notebook facts learned concerning the woodpecker. Also note dates on which transients are seen.

THIRD GRADE.

Continued work.—Study the plants being grown in window and porch boxes and give them proper attention. Thin the plants to a stand, carefully remove grass and weeds, water regularly, and do not permit the surface of the soil to bake. A sprinkler should be used in watering flowers.

Assigned work.—Begin planting early spring vegetables and flowers. The work suggested for the second grade applies here. Irish potatoes and English peas should also be planted.

Locate and collect specimens of weeds that are beginning to appear in yards, gardens, and along the roadway. Learn to recognize them at sight. If they can not be named send specimens to the State agricultural college for identification.

Practical work.—Care of box plants, planting vegetables and flowers, collecting, mounting, and labeling weeds furnish ample practical work. (See Farmers' Bul. 586.)

Correlations.—Language and drawing: Have each pupil make a drawing of his plat and locate and name each vegetable and flower planted. On the same sheet make a list of flowers and vegetables planted and give the dates, amount of seed, distance between plants, the depth to which planted, and the approximate date each plant should be ready for the table.

ANIMALS.

Continued work.—Review the lessons with the dog. Continue to note the migration of birds. The following are permanent residents: Flicker or yellow hammer, partridge, bobolink, mourning dove, sparrow hawk, tufted titmouse, wild turkey, cardinal or redbird, screech owl, American crow, Carolina chickadee, red-eyed vireo,

white-breasted nuthatch, brown thrasher, house wren, song sparrow, chipping sparrow, English sparrow, downy woodpecker. The following are some of the winter residents: Red-winged blackbird, robin, meadow lark, purple finch, crow blackbird, yellow-bellied sapsucker, junco, red-bellied woodpecker, phoebe, towhee or chewink. Add others to each list. Note the disappearance of winter residents. Be on the lookout for transients. The following are some of the transients that may be seen this month or next: Wild geese, wild ducks, hermit thrush, wood thrush, bobolink, Baltimore oriole, ruby-crowned kinglet. Note others as well as these and record the dates on which they are seen.

Assigned work.—Have the class study the sheep this month according to the following outline:

- (1) How many breeds of sheep in the community? Name them.
- (2) How does the coat of the sheep differ from other animals studied?
- (3) What are the enemies of sheep?
- (4) Do their feet and legs enable them to escape from their enemies?
- (5) Why are men sometimes referred to as following "like a flock of sheep"?
- (6) Do sheep fight? How?
- (7) How do males differ from females in some breeds? How does the sheep show anger?
- (8) Can sheep see and hear well? How does the sheep's eye differ from the cow's? What is the position of the sheep's ear? When it is peaceful? When there is danger?
- (9) Does the sheep chew its cud like a cow?
- (10) Why does the lamb have such long legs? What becomes of the lamb's long tail? How does the lamb play?
- (11) How much of the sheep's language is understood? Imitate.
- (12) What do sheep like to eat?
- (13) For what purposes are sheep kept—wool, meat, milk?
- (14) What animal is used sometimes to guard sheep? Have the pupils of the class seen a collie?

Practical work.—Noting and recording facts with reference to the migration of birds and studying sheep as suggested in the foregoing outline provide ample practical work.

Correlations.—Language: Make a list of the different breeds of sheep found in the community in the class notebook. Also record the facts learned about sheep.

Drawing: Clip from farm papers and other sources pictures of different breeds of sheep, paste them in the class notebook and label them. Make a sketch of a sheep.

FOURTH GRADE.

PLANTS.

Continued work.—The garden work should be kept up. Transplant cabbage, lettuce, and eggplants; sow turnips, radishes, spinach, and carrots; and plant Irish potatoes and onion sets. The soil

should be thoroughly prepared and well fertilized. Vegetables with small seed should be planted on a ridge or bed.

Assigned work.—With the assistance and direction of the teacher pupils of this grade should set plants for a permanent screen. The help of older pupils should be secured, but let it be the enterprise of this class. The snowball makes a beautiful screen for unsightly places. If the school grounds are not inclosed, secure California privet plants and set them this month. Make a ditch around the school grounds 10 to 12 inches deep and 12 inches wide. Fill the ditch half full of a mixture of manure and soil. Set the plants in single or double rows 12 inches apart. Finish filling in with soil to the depth that the plants stood in the nursery.

Practical work.—The work provided for in the foregoing directions should be done either after school hours or on the weekly holiday. If it is desired to set a privet hedge, one or more of the patrons should be invited to contribute the manure and haul it to the school yard. If the school yard is quite large, one of the patrons should bring a turn plow along with which to make the excavation for the plants. The pupils of this grade should be required to take notes on the several steps in the planting process.

Correlation.—Language: Develop the foregoing notes and copy them in the class book.

Drawing: Make a sketch of a privet plant showing roots, stem, and branches.

Arithmetic: Develop problems as to the number of privet plants required to make a hedge around the school yard; also as to the cost of the plants.

ANIMALS.

Continued work.—The study of birds and wild mammals should be kept up as suggested in January. What is "ground-hog day"? Continue collecting and studying cocoons. Store them for observation and study.

Assigned work.—Twig girdlers puncture and lay eggs in small twigs and then girdle the twig so that it breaks off and falls to the ground. Have pupils look for twigs of hickory or pecan trees lying on the ground or hanging on the trees. Note how they have been cut off. Examine the twigs close to the buds to find small punctures. Cut away the bark and determine whether there is an egg or grub present. All twigs lying on the ground or hanging on the trees should be removed and burned during the winter.

Look under the bark of dead or dying pine trees for pine weevils, bark-beetles, and sawyers.

Practical work.—Studying and making notes on birds and mammals, and looking for cocoons and twigs provide outdoor work. A number

of twigs should be brought to school to study in class. Place punctured parts in a bottle and watch developments.

Correlations.—Language and drawing: Make a sketch of a punctured twig and the egg of grub found. Accompany the drawings with a brief description covering such points as the appearance of the girdled end, the location and appearance of the puncture, and the appearance of the grub and egg.

Geography: Compare the ways in which insects, birds, and wild mammals spend the winter. Some go to sleep, others migrate to a warmer climate, and still others remain active. Give reasons.

FIFTH GRADE.

PLANTS.

Continued work.—The study of the special tree should be kept up. Special attention should be given to the buds. Note the arrangement on the stem, the outer coverings, and the sizes of buds. Note the condition of the buds of different sizes. Are some swelling? Make notes of all observations.

Assigned work.—The pupils of this grade should assist the fourth-grade pupils with their practical work. The gardens should be started either at home or at school. (See planting table in Appendix.)

During the month of February shade trees should be planted on the school ground. Under the guidance of the teacher and with the help of other pupils the fifth-grade pupils should assume the responsibility of this project. Among the trees that make good shades are silver maple, water oak, live oak, and weeping willow. (See Farmers' Bul. 134, for planting directions.) Trees for shade and decoration are of so much importance to the school yard that the pupils of this grade should plan an Arbor Day. The twenty-second day of February is an appropriate occasion. Secure the cooperation of the patrons and make it a community affair. Let a part of the day be devoted to the rendering of an appropriate program of exercises.

Practical work.—Gather twigs of the special tree for study in the class. The garden work consists of preparing and fertilizing the soil, sowing seeds, and transplanting the vegetables that have been started in the hotbed. The work in the planting consists of locating and securing trees, deciding on a planting plan and securing the cooperation of friends and patrons of the school in providing fertilizers, hauling the trees, making the excavations, and setting the trees. Have pupils take notes on the various lines of work.

Correlations.—Language: Develop and copy in the class book the notes on practical work.

Drawing: Make an outline drawing of the tree-planting plan, showing the location and the name of each tree.

Geography: From what locations were the trees for the school ground secured? Did they grow on upland or lowland? Do they require much or little moisture?

Arithmetic: Develop problems on the cost of trees planted in the school yard.

ANIMALS.

Continued work.—Continue the studies with the special bird group. Note the coming and going of members of the group, their methods of securing food, the places frequented, and whether they are found in flocks or alone.

Do any members of the special group of mammals come out of winter quarters this month? The woodchuck or groundhog? The chipmunk or ground squirrel?

Assigned work.—Pupils in the extreme southern part of the country should look for the citrus white fly. It is found on the plants of citrus fruit, cape jessamine, and privet. The insect is in the pupa or dormant stage. It is oval in shape, has a thin light-green case, and is found under edges of bark. Have pupils secure specimens and bring them to school for study and identification. Store some in a bottle and note developments.

By following turnplows this month white grubs, cutworms, and beetles may be found. Pull loose bark away from stumps in fields and collect insects found there. Study to identify them. Send those that can not be identified to the State agricultural college, with the request that the name and the helpful or harmful characters be furnished. (See Farmers' Bul. 606.)

Have pupils examine seed Irish potatoes for scale and blight. The blight is indicated by the presence of brown, sunken spots on the skin extending into the flesh of the tuber. Affected seed should either be discarded or treated with formalin solution before being planted.

Practical work.—Take notes on observations with birds and mammals and copy them in the class notebook. Collect, identify, mount, and label insects as suggested in the foregoing studies. (See Farmers' Bul. 606.)

Correlations.—Language: Have all the members of the class write letters to the State experiment station with reference to insects being sent for identification. Select the best one and mail it.

Drawing: Make drawings and label the insects studied this month.

Reading: Have the class read selections from Farmers' Bul. 606.

History and geography: What connection has the Baltimore oriole with American history? Who was Lord Baltimore? Where did he settle? Why did he come to America? What are the colors of the oriole? What were Lord Baltimore's colors? Does this fact account for the name of the bird?



BLACKBOARD SUGGESTION FOR A SPRING MONTH.

MARCH.

(Plate V.)

FIRST AND SECOND GRADES.

PLANTS.

Continued work.—Window and porch boxes should receive careful attention. Water frequently with a sprinkler and do not let the surface soil bake. Early planted vegetables need attention. Stir the soil around the plants. See that plants are thinned to a proper stand. Continue the work of learning to recognize plants that are blooming.

Do not permit the soil of flower beds and borders to bake. As soon as the surface soil dries after a hard rain, stir it gently with a hand rake. Keep grass and weeds removed.

If any garden plants or flowers grow slowly, it will be well to make an application of liquid manure. To prepare liquid manure secure a barrel, tub or candy bucket, a fertilizer sack, and some barnyard manure. Place manure in the sack equal to one-half the capacity of the vessel used, tie the mouth of the sack and place it in the vessel. Finish filling with water. The water in a few days becomes dark brown in color. Before using it dilute to a light brown. As the liquid manure is removed add more water.

Assigned work.—Sow pepper and tomato seeds in hotbeds or boxes. Water carefully. Germinating boxes may be made by following the directions for making window or porch boxes given in the January exercise.

Have pupils bring to the class a few radish, cabbage, lettuce, and garden pea plantlets. Have them name the parts—roots, stems, leaves. Which part in each case is used for food? Why? Compare the roots, stems, and leaves as they appear now.

Practical work.—Care for the plants growing in boxes and in the gardens. Keep records of work done. With the assistance of older pupils prepare some liquid manure. If the school has not a hotbed, make a germinating box for tomatoes and peppers.

Correlations.—Language: Describe a germinating box.

Drawing: Make outline sketches of the plantlets studied, showing roots, stems, and leaves.

ANIMALS.

Continued work.—This is an interesting month with the birds. Transients are on their way north and the summer residents are putting in their appearance. Have the pupils make observations at home, on the way to school, and on the school grounds, and report the names of all birds seen this month. Have the pupils describe

those that they are unable to name and assist them in naming them. (See Farmers' Buls. 506 and 630.)

Assigned work.—The robin does not nest in the South but it is of so much interest that it should be given special attention this month. It spends a few days in each State on its way north. Have the pupils study it according to the following outline:

- (1) What is the color of the robin's head? Breast? Back?
- (2) Where is it seen?
- (3) Is it alone or in company with its fellows?
- (4) What is the robin eating?
- (5) Where does it obtain its food?
- (6) Have the males and females the same color?
- (7) Imitate its note.

Practical work.—Making observations to learn the names of birds and making special studies with the robin provide field work.

Correlations.—Language: Have pupils record in their notebooks the results of their studies with the robin.

Drawing: Have the pupils of the class sketch the robin and add the proper colors with crayons.

Reading: Read to the class *How the Robin Came*, by J. G. Whittier.

THIRD GRADE.

PLANTS.

Continued work.—Look after the window and porch boxes and continue planting early spring vegetables. Recognition work with weeds and wild flowers occurring in yards, gardens, orchards, pastures, and along the roadway should be kept up. Any that can not be identified should be sent to the State agricultural college with the request that they be named.

Assigned work.—The study of weeds is one of the most important phases of nature study. The pupils of this grade should become familiar with the most economically important ones. The following outline suggests a plan of study:

- (1) Name the weeds found in the garden.
- (2) Name those found in the home yard.
- (3) Name those found in the orchard.
- (4) Name those found in the pastures.
- (5) Name those found along roadsides.
- (6) What sort of root has each plant?
- (7) Did the weed grow from an underground stem or from a seed?
- (8) How is it protected from being eaten by animals? Thistles? Prickly leaves? Bitter juices?
- (9) How may each plant be destroyed?

Practical work.—Collect specimens of all weeds and wild flowers found this month. Examine them carefully for identification.

Mount on cardboard and label specimens of leaves and roots. Leaves should be dried carefully between blotting paper before mounting.

Correlations.—Language: Copy carefully in the notebook facts learned about weeds. The record of each weed should include the name, where found, from what it grew, the kind of root it has, how protected from animals, how it can be destroyed, and any other facts learned about it. Learn to spell all new names.

Drawing: Make a drawing of the entire weed and separate drawings of the root and leaf.

Reading: Have the pupils read selections on collecting and mounting plants found in Farmers' Bul. 586.

ANIMALS.

Continued work.—Review the lesson with sheep. Keep up the study of migration of birds as suggested in the February exercise. Note the winter residents that are leaving, the transients that are passing by, and the summer residents that are returning. The following are summer residents: Barn swallow, blue jay, mocking bird, American cuckoo or rain crow, bluebird, humming bird, catbird, purple martin, kingbird, nighthawk, and sparrow hawk. Are there others?

Assigned work.—Have the class study the goat this month, using the following outline:

- (1) Compare the goat with the sheep as to size, coat, and horns.
- (2) How do goats defend themselves?
- (3) Do their feet and legs enable them to escape from their enemies? What are their enemies?
- (4) What facial appendage has the goat that gives it a comical appearance?
- (5) Can goats see and hear well? What is the position of the goat's ears when it is peaceful? When frightened?
- (6) Does the goat chew its cud?
- (7) How much of the goat's language is understood? What does each particular cry indicate?
- (8) What do goats like to eat?
- (9) For what purposes are goats raised? Hair? Meat? Milk?
- (10) What are young goats called?

Practical work.—Ample work is provided in making observations with birds and in studying the goat. Notes should be taken while observations and studies are being made.

Correlations.—Language: Write neatly in the notebook the names of all birds studied and the results of studies with the goat. Let the facts about goats be woven into a short story.

Drawing: Make a drawing of a goat. Collect any pictures that may be found and paste them in the notebook, properly labeled.

FOURTH GRADE.

PLANTS.

Continued work.—Look after the growing garden plants and continue the work of planting. (See the planting table in the Appendix.) Tomato, cabbage, and pepper seeds should be sown in hotbeds or germinating boxes.

Complete the work of setting hedges, permanent screens, and other shrubbery. List the shrubs that are blooming or putting forth leaves.

Assigned work.—What field crops are being planted this month—clover, alfalfa, oats, early corn, grasses, other crops? Answer the following questions as to each crop that is being planted:

- (1) How is the seed bed prepared?
- (2) How are the seeds planted—in drills, broadcast? What quantity is planted per acre?
- (3) If drilled, are the seeds planted on beds or in open furrows?
- (4) How are the seeds treated before being planted—inoculated, dipped in solution to prevent diseases?
- (5) How are seeds planted—by hand, with seeders?
- (6) Is fertilizer applied? How?
- (7) For what is the crop grown—hay, grain?
- (8) When will the crop be ready for use?

Practical work.—Each pupil should provide himself or herself with a pocket notebook in which to take notes on the work done in the garden and on the facts learned in connection with the plants being studied according to the foregoing outline. The pupils should make inquiry at their homes to ascertain the facts called for. These should be discussed in the class. Have the pupils bring to school a few specimens of seed being planted at their homes. Make permanent mounts of any that have not been previously mounted. (See Farmers' Bul. 586.)

Correlations.—Language: Weave into a short written story the facts learned with reference to one of the field crops. Record in the class book the facts learned with reference to the several plants studied and also the principal facts in connection with the garden operations.

Drawing: Make drawings of all seeds being planted in the fields at this time.

Arithmetic: Develop problems on the number of pounds or bushels of the seeds necessary to plant given areas.

ANIMALS.

Continued work.—The study of birds and wild mammals should be kept up. Some animals that have been in the sleeping state are now waking up and moving about. Among them are the chipmunks, woodchucks, flying squirrels, and bats.

This class has studied birds grouped according to the manner in which they catch insects. It is interesting to note what the different groups of birds are eating and how they gather food in the absence of an abundant supply of insects.

Continue collecting cocoons and storing them in bottles for study as previously described.

New assigned work.—The pupils should be taught with great emphasis the danger from flies. This is the time of year to begin combating them. Each fly destroyed now represents thousands later in the summer. All windows and doors of the house should be screened. Study the fly according to the following outline:

- (1) Examine the fly's eyes. Do they appear like honeycomb? Are there a number of little eyes? Is there a dot on top of the head? This consists of three eyes.
- (2) How many wings has the fly? What is the color of the wings? Are they transparent?
- (3) How many legs has the fly? Examine the legs and count the joints.
- (4) What is the color of the fly's body?
- (5) Can you see the fly's tongue when it eats? Can you feel it when the fly eats from your hand?
- (6) How does a fly clean its head? Front feet? Middle feet? Hind feet? Its wings.
- (7) How does a fly carry disease? What diseases do flies carry?
- (8) Where do flies lay their eggs?

FIFTH GRADE.

PLANTS.

Continued work.—A close watch should be kept on the special tree being studied by the class. Note the dates it blooms or puts on leaves. Mount and label specimens of these.

Assigned work.—Have pupils prepare a table similar to the following and fill in the facts indicated by the headings with reference to all orchard and forest trees:

Table of plant facts.

Name of plant.	Orchard or forest.	Date leaves first appear.	Date leaves become common.	Date blooms first appear.	Date blooms become common.

Have the pupils collect the following information at their homes and report to the class:

- (1) What fruit trees are being sprayed this month?
- (2) For what purpose are they sprayed?
- (3) What sprays are used?

Record these facts in notebooks.

Practical exercises.—Preparing tables and collecting the facts called for in the foregoing lessons supply ample work for the pupils while out of the class.

Correlations.—Language: Tabulate the facts with reference to trees and write up the observations in connection with spraying.

List new words and learn to spell them.

Drawing: Make drawings of leaves and flowers that appear this month.

Geography: Note the locations of plants that are earliest in putting forth blooms and leaves. Are they on hilltops or in low places? On the south side or the north side of hill or mountain? Give reasons.

ANIMALS.

Continued work.—Continue the studies with the special group of birds. Note the coming and going of members of the group, their method of securing food, the places frequented, and whether they are found in flocks or alone.

What members of the special group of mammals are putting in their appearance? What are they eating? Are they providing summer homes? Where? What kind?

Assigned work.—The chief reason for studying the mosquito in the South is that one kind (genus) is the means of transmitting malaria. This is quite a common disease and does much to incapacitate southern people for efficient work. The idea that malaria originates in swampy or marshy places is entirely erroneous. The disease is transmitted solely through the anopheles mosquito. In most cases the disease may be controlled by the use of quinine under the direction of a physician, but the best method is to control or destroy the mosquitoes.

Have the pupils make a study of mosquitoes, at the same time emphasize the importance of keeping the home premises free from them. These pestiferous insects soon begin to put in their appearance if preventive measures are not taken. Instruct the pupils to rid their premises of all discarded tin cans, jars, buckets, and the like, drain pools of water, and fill wells that are no longer in use. Those places that can not be drained should have their surfaces covered with oil. Let the following outline serve as a guide in the study of the mosquito:

- (1) Collect all the kinds of mosquitoes that can be found.
- (2) Name and describe each kind.
- (3) Do the males or females bite?
- (4) When at rest, which kind is short and humpbacked? Which kind stands with hind legs in the air?
- (5) Which kind has spotted wings?
- (6) Which kind bites during the daytime? Yellow-fever mosquitoes.
- (7) Why are outbreaks of yellow fever no longer common in the South?
- (8) How does the mosquito transmit malaria?
- (9) How does malaria affect the farm operations of the community? Would the farmers of the community be able to make larger and better crops if this disease did not exist?
- (10) Get a small bottle of stagnant water containing wrigglers (wiggle-tails). Have the pupils examine these closely. These are the larvæ of mosquitoes.
- (11) Why does kerosene oil poured on the surface of water kill or prevent mosquitoes?

(For information covering the foregoing outline see Farmers' Buls. Nos. 444, 450, and 547.)

Practical work.—Collect different kinds of mosquitoes and place them in bottles for study. Have members of the class bring to school small bottles of stagnant water containing mosquito eggs and wrigglers.

Correlations.—Language and drawing: Make sketches and write descriptions of wrigglers and adult mosquitoes.

APRIL AND MAY.

FIRST AND SECOND GRADES.

PLANTS.

Continued work.—Continue to care for the window and porch boxes. Plant additional vegetables (see planting table); gather those ready for the table and study plants as suggested for the preceding month. Teach pupils the names of all plants that are putting out flowers. Names of plants should be written on the blackboard and copied in the pupils' booklets.

Assigned work.—Have the pupils of this grade plan their part in the early spring vegetable show. Selecting, preparing and arranging vegetables for display provide interesting and instructive work.

It is now time to plant some of the later flowers and vegetables such as dahlias, zinnias, cosmos, peppers, tomatoes, and cabbage.

Practical work.—There is abundant work provided for in carrying out the suggestions contained in the foregoing outline.

Correlations.—Have members of the class tell about the things seen at the show this month.

Drawing: Make sketches of vegetables now ready for the table. Make simple drawings of flowers and leaves.

ANIMALS.

Continued work.—The summer birds are back home again. They have put on their new coats and are singing their sweetest songs. It is now mating time—the happiest season of the year with the birds. Soon they will be building their nests. It is an easy matter at this time to direct the attention of the pupils to bird study. Have the pupils make a list of the birds now to be seen, describe their colors and learn to imitate their notes or songs.

Assigned work.—Study the catbird according to the following outline:

- (1) Where does the catbird build its nest?
- (2) Is the squall of the catbird like the mew of a cat? When and why is this note used?
- (3) Does the catbird imitate the songs of other birds? What other bird does this?
- (4) Compare the catbird and the mocking bird as to appearances.
- (5) Compare the catbird and robin as to size, shape, and color.
- (6) What is the color of the catbird's head, neck, wings, tail, breast, underparts?
- (7) What do catbirds eat? What places do they frequent?

Practical work.—The pupils are amply paid for the time spent in studying birds during April and May. When going out to make observations they should take notebooks and make a record of the facts learned. In taking notes on birds that the pupils are learning to recognize use the following form:

Bird notes.

Name of bird.....
 Where seen.....
 Color: Head..... Breast..... Tail.....

Correlations.—Language: Copy in class notebook the names of birds and facts learned concerning them. Learn to spell all new names. Have each pupil relate orally an experience with birds.

Drawing: Sketch a bird.

THIRD GRADE.

PLANTS.

Continued work.—Continue the work with plants as outlined for March.

Practical work.—Continue collecting, mounting and labeling specimens of weeds and wild flowers as suggested in March exercise. Make preparations for vegetable show.

Correlations.—For language, drawing and reading follow the suggestions for the preceding month.

ANIMALS.

Continued work.—By examining the notebooks answer the following questions: How many birds has the class learned to recognize this

year? Name the permanent residents, the summer residents, the winter residents, and the transients.

Review the lesson with the goat. What animals has the class studied this year? Which proved the most interesting? Which does the class consider the most useful? Where there are differences of opinion have the pupils give the reasons.

Assigned work.—Require the pupils of this class to make a collection of snails, earthworms, crayfish, daddy longlegs or grandfather graybeards and spiders. Place these in bottles and tin cans. Have the pupils study these closely to be able to answer questions with reference to the parts of their bodies, their methods of moving about, how they defend themselves and what they eat and how they secure it. Many interesting facts may be learned from a study of these little animals.

Practical work.—Securing bottles and cans and searching for the small animals mentioned in the foregoing lesson provide abundant outdoor work.

Correlations.—Language: Have the pupils describe briefly each of the small animals studied.

Drawing: Make sketches of the snails, spiders, and other small animals.

FOURTH GRADE.

PLANTS.

Continued work.—Look after the growing garden plants, continue the work of planting (see planting table, p. 62), and gather vegetables now ready for the table. Have the pupils of this grade prepare their exhibits for the early spring vegetable show.

Seeds of plants providing temporary screens and backgrounds and of climbing plants should be sown. Four o'clocks and hollyhocks belong to the first group mentioned, and morning glories, ornamental gourds, and climbing nasturtiums to the second. The pupils of this grade should be encouraged to grow these plants both at home and at school.

Assigned work.—What field crops are being planted during April and the first part of May—corn, cotton, sorghum, sugar cane? What other crops?

Answer the following questions as to each crop that is being planted:

- (1) How is the seed bed prepared?
- (2) Are the seed planted in furrows or in beds?
- (3) What quantity of seed in each case is planted per acre?
- (4) How are seeds planted—by hand, with planters?
- (5) What distance apart are the rows? How far apart are the seed planted?
- (6) Is fertilizer applied? How? In what quantity in the case of each crop?
- (7) For what is the crop grown?
- (8) When will each crop be ready to harvest?

Practical work.—Use the pocket notebooks to take notes as indicated by the questions on crops. Also require notes to be taken on the work that is done in the pupil's garden plat either at home or at school.

Have pupils bring to school and mount specimens of all kinds of seeds being planted at this time. (See Farmers' Bul. 586.)

Correlations.—Language: Copy in the class notebooks the information gathered with reference to field crops.

Drawing: Make drawings of seeds being planted at this time.

Arithmetic: Develop problems on the quantity and value of seed of each kind being planted this month.

ANIMALS.

Review the lesson with flies. Continue the work with birds as to the manner of catching insects.

Assigned work.—Fleas are a nuisance and are known to carry disease. Pupils should be taught their characteristics and how to combat them. Have the pupils examine the dogs and cats at their homes for fleas. Have some brought to school in small bottles for examination.

- (1) Fleas are closely related to flies. How do they differ?
- (2) Explain why the flea has lost its wings?
- (3) Is it due to the fact that it subsists on other animals (parasite) and does not need the wings?
- (4) Have each pupil tell how fleas are combated at his or her home.

(Farmers' Bul. 683.)

Take up again the study of an ant colony. How many kinds are found in a colony? What differences are noted in size? In shape of head? In shape of body? What is the character of work done by each kind?

Practical work.—Use the pocket notebooks and take notes on the flea and the ant. Bring to school in small bottles a few specimens of each for study in class.

Correlations.—Language: Have each pupil write out detailed directions for destroying fleas.

Drawing: Make an enlarged drawing of a flea. Make drawings of different kinds of ants.

Reading: Read to the class Proverbs XXX, 24-28.

FIFTH GRADE.

PLANTS.

Continued work.—Continue the compiling of facts with reference to orchard and forest trees. Use the table suggested for March.

When the special tree being studied by the class is in full foliage make an outline drawing of it. Compare this drawing with those of previous months.

Assigned work.—The strawberry is one of the most interesting and delightful of the small fruits. Use the following outline as a guide in studying the strawberry plant and fruit:

- (1) How should strawberries be planted—in rows? How far apart should rows be? How far apart should plants stand in the row? Is April a good time to plant strawberries?
- (2) From what do strawberry plants grow—seeds, runners?
- (3) Examine a strawberry plant in the class. What kind of root—fleshy, branching? Color of the root? How are the leaves arranged? How many leaflets in each group?
- (4) Examine a strawberry blossom. How many parts are there to the hull or calyx? How many parts are there to the blossom? Is there a green button in the center of the blossom? Are the blossoms found in clusters? Do they all open at the same time? What parts of the flower fall away and what parts remain? What insects visit strawberry blossoms? In what way are they helpful?
- (5) Examine several ripe strawberries. Are they all the same shape and color? What are the specks on the surface of the berry—seed? Is the berry the same color on the surface as it is within? How many kinds of strawberries are grown in the community? Name them.

Practical work.—Gather data with reference to orchard and forest trees. Bring to school strawberry plants, blossoms, and fruit for class study. Let the members of this class also join in the early spring vegetable show.

Correlations.—Language: Have the pupils write a description of a strawberry plant, including the blossom and fruit.

Drawing: Make drawings with proper colorings of strawberry leaves, flowers, and fruit, both green and ripe.

Arithmetic: Develop problems involving the number of strawberry plants, the yield, and the value of yield from a given area.

ANIMALS.

Continued work.—Continue the studies as previously suggested with the special group of birds. Are they seen in pairs? Are they preparing to build nests? Note particularly the locations at which they are most commonly seen. What do such locations afford as to natural protection? Food supply? Nesting places?

Review the lesson on mosquitoes.

Assigned work.—The 12-spotted cucumber beetle is the parent of the southern rootworm or budworm of corn. This beetle may be found most everywhere at this time. It is recognized by 12 black spots on a yellowish-green background. Have the pupils collect specimens of these in small glass bottles and bring them to school for study.

During the months of April and May the pupils should make a large collection of insects. Mount and label these according to instructions found in Farmers' Bul. 606. Those insects which the

teacher and pupils are not able to identify should be sent to the State agricultural college with the request that they be named. By following this plan the pupils may become familiar with most of the insects in the community. The pupils of this class should secure the cooperation of all the pupils of the school in this campaign for a large collection of insects.

Practical work.—Abundant outdoor work is provided in the campaign for a collection of insects. For equipment, see Farmers' Bul. 606.

Correlations.—Language lessons and drawing: Make drawings and write brief descriptions of the principal insects found.

APPENDIX.

SOME GROUPS OF BIRDS.

- (1) *Thrushes and allies*.—Bluebird, robin, catbird, brown thrush, and mocking bird.
- (2) *Nuthatches, titmice, creepers, and wrens*.
Nuthatches.—White-breasted and red-breasted.
Titmice.—Chickadee or black-capped titmouse, long-tailed chickadee, and Carolina titmouse.
Creepers.—The brown creeper.
Wrens.—House wren, long-billed marsh wren, short-billed marsh wren.
- (3) *Warblers and vireos*.
Warblers.—Blue yellow-backed warbler, Nashville warbler, Tennessee warbler, yellow warbler or summer yellow bird, black-throated green warbler, American redstart, Maryland yellow throat.
Vireos.—Red-eyed, warbling, yellow-throated, and white-eyed.
- (4) *Shrikes, waxwings, swallows, and tanagers*.
Shrikes or butcher birds.—Great northern shrike, loggerhead shrike.
Waxwings.—Cedar waxwings or cedar bird.
Swallows.—Barn swallow, eaves or cliff swallow, white-bellied swallow, brink swallow, and purple swallow.
Tanagers.—Scarlet tanager, rose tanager or summer redbird.
- (5) *Finches and sparrows*.
Finches.—Evening grosbeak, pine grosbeak, purple finch, goldfinch or thistle bird, snowbird or snow bunting, and rose-breasted grosbeak.
Sparrows.—Vesper sparrow or grass-finch, tree sparrow, white-crowned, white-throated, field sparrow, Savanna sparrow, chipping sparrow, junco, or black snowbird, song sparrow, dickcissel (small "field lark"), and English sparrow.
- (6) *Blackbirds, crows, and jays*.
Blackbirds.—Purple grackle, bronzed grackle, red-winged blackbird, cowbird, bobolink, and meadow lark.
Crows.—Common, magpie.
Jays.—Blue.
- (7) *Fly catchers, humming birds, swifts, and night hawks*.
Fly catchers.—Phoebe or pewee, kingbird, great crested pewee, least crested pewee, and wood pewee.
Humming birds.—Rubythroat.
Swifts.—Chimney swift or chimney swallow.
Nighthawks.—Whippoorwill, nighthawk or bullbat.
- (8) *Woodpeckers, kingfishers, and cuckoos*.
Woodpeckers.—Ivory-billed, pileated woodpecker, hairy, downy, flicker, red-headed, and yellow-bellied sapsucker.
Kingfishers.—Belted kingfisher.
Cuckoos.—Yellow-billed, black-bellied.
- (9) *Owls*.
Barn owl, short-eared owl, barred owl, screech owl, long-eared owl, Acadian or saw-whet, elf, great horned, snowy owl, and burrowing owl.

(10) *Hawks, eagles, kites, and vultures.*

Hawks.—Sparrow hawk, broad-winged hawk, Swanson's hawk, rough-legged or hew hawk, red-shouldered hawk, red-tailed hawk, sharp-shinned hawk, Cooper's hawk, fish hawk, and marsh hawk or marsh harrier.

Eagles.—Bald, and golden.

Kites.—Swallow-tailed.

Vultures.—Turkey buzzard, black vulture or carrion crow, and California condor.

(11) *Pigeons, grouse, and shore birds.*

Pigeons.—Passenger pigeon, mourning dove, band-tailed pigeon.

Partridge and grouse.—Bobwhite, ruffed grouse, prairie hen, Columbian sharp-tailed grouse, mountain partridge, California partridge, and dusky grouse.

Plovers.—Ring-neck, killdeer, and golden.

Snipes.—American woodcock, American or Wilson's snipe, gray snipe or dowitcher, marbled godwit, Hudsonian godwit, willet, greater yellow-legs, upland sandpiper.

Curlews.—Long-billed or sickel-bill, Hudsonian, and Eskimo.

Phalaropes.—Wilson's, red, and northern.

Rails.—Clapper, king, Virginia, Carolina, black, yellow croke.

Gallinules.—Purple, Florida, coot, whooping crane and sand-hill crane.

Ibises.—White, wood, bittern or stake-driver.

Hérons.—Great blue, green, and great white egret.

(12) *Water birds.*

Ducks.—Mallard, black, wood or summer, whistler, old squaw, butterball, ruddy, American eider, king eider, and fish or mergansers.

Geese.—American white-fronted, snow, Canada or wild, and brant.

Swans.—Trumpeter, whistling.

Gamuts.—White and brown.

Darter.—Cormorant, pelicans—white and brown.

PLANTING TABLE.

SUCCESSION AND COMPANION CROPS FOR SCHOOL AND HOME GARDENING.

FALL AND WINTER CROPS—SEPTEMBER TO FEBRUARY 15.

Kind of vegetable.	Distance for plants to stand.		Depth of planting.	Time of planting.	Seeds or plants per 100 feet or rows.	Ready for use after planting.
	Between rows.	Between plants.				
Onions.....	1 to 3 feet....	3 to 5 inches..	1 to 1½ inches.	Sept.-Oct.	{Seed, 1 ounce. Sets, 1 quart.}	90 to 130 days.
Turnips.....	2 to 3 feet....	3 to 4 inches..	½ inch.....	Aug.-Sept.	½ ounce.....	60 to 80 days.
Carrots.....	1½ to 3 feet....	3 to 4 inches..	½ inch.....	Aug.-Sept.	1 ounce.....	75 to 100 days.
Lettuce.....	1½ to 2½ feet....	4 to 6 inches..	½ inch.....	Sept.-Oct.	½ ounce.....	60 to 90 days.
Radishes.....	1½ to 3 feet....	2 to 3 inches..	½ inch.....	Sept.-Oct.	1 ounce.....	20 to 40 days.
Spinach.....	1½ to 3 feet....	2 to 4 inches..	½ inch.....	Sept.-Oct.	1 ounce.....	30 to 50 days.

EARLY SPRING—FEBRUARY 15 TO MAY 15.

Onions (sets)...	½ to 3 feet....	3 to 6 inches..	1 to 1½ inches.	Feb.....	1 quart.....	60 to 90 days.
Lettuce.....	1½ to 2½ feet....	4 to 6 inches..	½ inch.....	Feb.....	½ ounce.....	60 to 90 days.
Turnips.....	2 to 3 feet....	3 to 4 inches..	½ inch.....	Feb.-Mar.	½ ounce.....	60 to 80 days.
Radishes.....	1½ to 3 feet....	2 to 3 inches..	½ inch.....	Feb.-Mar.	1 ounce.....	20 to 40 days.
Spinach.....	1½ to 3 feet....	2 to 4 inches..	½ inch.....	Feb.-Mar.	1 ounce.....	30 to 60 days.
Carrots.....	1½ to 3 feet....	3 to 4 inches..	½ inch.....	Feb.-Mar.	1 ounce.....	75 to 100 days.
English peas..	2 to 3 feet....	3 to 6 inches..	2 inches.....	Feb.-Mar.	½ pint.....	50 to 80 days.

VACATION PERIOD—MAY 15 TO SEPTEMBER.

Onions.....	1 to 3 feet....	3 to 6 inches..	1 to 1½ inches.	May.....	{Seed, 1 ounce. Sets, 1 quart.}	90 to 130 days.
Cabbage.....	2½ to 3 feet....	2 to 2½ feet....	½ inch.....	May-June.	½ ounce.....	90 to 130 days.
Pepper.....	2½ to 3 feet....	1 to 1½ feet....	½ inch.....	May-June.	1 ounce.....	100 to 140 days.
Irish potatoes.	2½ to 3 feet....	1 to 1½ feet....	2 to 3 inches..	May.....	5 to 6 pounds.	80 to 140 days.
Pumpkins.....	6 to 8 feet....	6 to 8 feet....	1 to 1½ inches.	May.....	½ ounce.....	100 to 140 days.
Tomatoes.....	3 to 4 feet....	2½ to 3 feet....	½ to ¾ inch....	May.....	1 ounce.....	100 to 140 days.
Beets.....	2 to 3 feet....	3 to 5 inches..	½ to 1 inch....	May.....	2 ounces.....	60 to 80 days.
Parsnips.....	2 to 3 feet....	3 to 4 inches..	½ inch.....	May.....	½ ounce.....	125 days.

REFERENCES.

The publications referred to in this bulletin may be had as long as available by writing to the United States Department of Agriculture, Washington, D. C. The following is a list of the references: Farmers' Bulletins Nos. 54, Some Common Birds; 134, Tree Planting on Rural School Grounds; 157, The Propagation of Plants; 196, Usefulness of the American Toad; 243, Fungicides and Their Use in Preventing Diseases of Fruits; 255, The Home Vegetable Garden; 369, How to Destroy Rats; 440, Spraying Peaches for the Control of Brown-rot Scab, and Curculio; 442, The Treatment of Bee Diseases; 444, Remedies and Preventives Against Mosquitoes; 447, Bees; 450, Some Facts About Malaria; 456, Our Grosbeaks and Their Value to Agriculture; 496, Raising Belgian Hares and Other Rabbits; 497, Some Common Game, Aquatic, and Rapacious Birds in Relation to Man; 506, Food of Some Well-known Birds of Forest, Farm, and Garden; 512, The Boll-weevil Problem; 547, The Yellow-fever Mosquito; 548, Storing and Marketing Sweet Potatoes; 586, Collection and Preservation of Plant Material for Use in the Study of Agriculture; 606, Collection and Preservation of Insects and Other Material for Use in the Study of Agriculture; 630, Some Common Birds Useful to the Farmer; 660, Weeds: How to Control Them; 670, Harvest Mice as Farm and Orchard Pests; 679, House Flies. Bureau of Entomology Circular No. 34, House Ants.

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PROFESSIONAL PAPER.

October 15, 1915

SOME EFFECTS OF SELECTION ON THE PRODUCTION OF ALKALOIDS IN BELLADONNA.

By A. F. SIEVERS,

Chemical Biologist, Drug-Plant and Poisonous-Plant Investigations.

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INTRODUCTION.

The improvement of many of our important agricultural crops has been brought about by means of plant selection and breeding, and similar methods are being extended to various other fields of plant production in the hope of achieving similar results.

With a few exceptions, the growing of medicinal plants is still in its early stages, and it is a much-debated question whether these plants when cultivated lose any of their therapeutic properties; but with the constantly diminishing supply of many of our important native drug plants cultivation becomes more and more imperative. Also, the quality of some of the drugs on the market has deteriorated to such an extent that improvement is much to be desired, and it is hoped that this may be accomplished through the methods employed by the plant breeder.

Atropa belladonna is an important mydriatic drug, the supply of which has been of such inferior quality in recent years that the Office of Drug-Plant and Poisonous-Plant Investigations has been conducting experiments for some time with special reference to increasing the alkaloidal content of the plant. The first step was to make a general study of the plant with regard to individual variation

of the alkaloidal content; then to study the relation of physical and chemical characteristics—the influence of environmental factors, such as climate and soil—and the fluctuations in the alkaloidal content during the growing season. The results of these investigations have already been reported.¹

SELECTION OF TYPICAL PLANTS.

A number of plants were selected which from the data obtained in the preliminary investigation showed typical alkaloid-producing tendencies. Although only those plants which produce a high percentage of alkaloids are of commercial value, plants of the opposite type, namely, those which produce only small quantities, were also selected, in order to furnish more comprehensive data on the transmissibility of alkaloid-producing characteristics. An enumeration of the individual plants which were selected from the original lot, showing the alkaloidal content of their leaves at the various stages of growth during two seasons, is given in Table I.

TABLE I.—*Alkaloids in the leaves of selected belladonna plants during two seasons, at Arlington, Va.*

Plant No.	Yield of alkaloids on which selection was based.	Alkaloidal content (per cent).												
		Stage of growth, 1911.						Stage of growth, 1912.						
		First.	Second.	Third.	Fourth.	Fifth.	Average.	First.	Second.	Third.	Fourth.	Fifth.	Average.	
34.....	Low.....	0.335		0.526	0.532	0.200	0.414	.....	0.292	0.320				0.406
3.....	do.....	.384	0.375	.277	.549	.451	.407	.....	.393	.448	0.448			.426
23.....	do.....		.348	.354	.487	.425	.403	0.496	.366	.341				.401
46.....	do.....	.337	.285	.308	.588	.431	.390	.418	.334	.480	.483	0.314		.406
13.....	Medium.....	.614	.627	.626	.763	.563	.639	.495	.479	.655	.472	.488		.518
12.....	High.....	.649	.782	.693	.497	.584	.641	.767	.631	.685	.715	.394		.638
7w.....	do.....	.558	.831	.832	.727	.571	.704	.782	.666	.646	.694	.573		.672
6w.....	do.....	.596	.879	.925	.711	.722	.766	.847	.747	.882	.804	.558		.768

METHOD OF CONTROLLING POLLINATION.

The flowers of *Atropa belladonna* are normally cross-pollinated and depend principally on insects, such as moths, beetles, and bumblebees, for the transportation of pollen. When insects are excluded the flowers fail to develop and soon drop off, which indicates that natural self-pollination occurs rarely, if at all.

In 1911 a large number of flower buds were inclosed in manila bags in the hope that close pollination would take place, but none of the flowers set seed. However, seeds resulting from the cross-pollination of the individual plants enumerated in Table I were collected and planted in flats in the greenhouse at Arlington, Va., in the following

¹ Sievers, A. F. Individual variation in the alkaloidal content of belladonna plants. *Journal of Agricultural Research*, v. 1, no. 2, p. 129-146, 1913.

January. Late in April, when the plants from these seeds were about 3 or 4 inches high, they were transplanted to the field.

In 1912 a second attempt was made to secure seeds from close-pollinated flowers, and in order to insure fertilization the pollen was transferred to the stigmas by hand before the flowers were inclosed. The method of bagging the flower buds used in the previous year again proved ineffectual, since a species of aphid bred in the bags in great numbers and destroyed the young plant tissues. Seeds were obtained from a number of selected plants which had been inclosed in cheesecloth cages, but even within those cages the aphides often multiplied to such an extent as to injure the plant. The seeds from these plants were sown in flats in the greenhouse and the seedlings therefrom transplanted to the field, the same as in 1911.

FIRST-GENERATION PLANTS FROM CROSS-POLLINATED PARENTS.

The plants from the seed of the cross-pollinated selected individuals in 1911 were transplanted to the field late in April. There were from 6 to 15 individual plants from each parent. These plants made a fairly rapid growth and by midsummer were in full bloom, but the growth they had made was not sufficient to make possible a picking from each individual plant. A collective sample was therefore secured from each set of individuals derived from the same parent. On August 30, when the berries were partially ripe, the second picking was made. In picking these samples care was taken to get leaves from all the individuals, so that the results of the assay would indicate as nearly as possible the average percentage of alkaloids in the leaves of the individuals. Table II shows the results of the assays.

TABLE II.—*Alkaloids in the leaves of first-generation belladonna plants grown from cross-pollinated selected parents at Arlington, Va.*

Parent plant.		Alkaloidal content (per cent).			Parent plant.		Alkaloidal content (per cent).		
No.	Yield of alkaloids.	First picking.	Second picking.	Average.	No.	Yield of alkaloids.	First picking.	Second picking.	Average.
34.....	Low....	0.524	0.693	0.609	12.....	High....	0.650	0.882	0.766
3.....	do....	.479	.518	.498	7w.....	do....	.617	1.063	.840
13.....	Medium	.640	.859	.750	6w.....	do....	.805	1.282	1.043

From Table II it is evident that these first-generation plants displayed largely the characteristic of the parent plants as regards alkaloid production. Plants 7w and 6w merit special attention, their leaves containing more than 1 per cent of alkaloids.

The following season, 1913, these plants were large enough to furnish samples from each individual, and pickings were made at four stages of growth during the season. The first picking was on May 6, before flowering; the second on May 23, when the plants were in full

bloom; the third on June 21, when the first berries were developing; and the fourth on September 8, when most of the berries were ripe and much new growth had appeared in the form of shoots and suckers. The season was a very unfavorable one, and the plants made a rather small growth, so that during July and August the leaves were too small and sparse to secure samples. For the purpose of comparison, Table III gives the alkaloidal content of the various samples and the average for the season, the average alkaloidal content of each picking being summarized at the close.

TABLE III.—*Alkaloids in the leaves of individual first-generation belladonna plants at various stages of growth at Arlington, Va., during the second season, 1913.*

Plant No.	Alkaloidal content (per cent).					Plant No.	Alkaloidal content (per cent).				
	First stage, May 5.	Second stage, May 23.	Third stage, June 21.	Fourth stage, Sept. 8.	Average for season.		First stage, May 5.	Second stage, May 23.	Third stage, June 21.	Fourth stage, Sept. 8.	Average for season.
34 ₁		0.316	0.324		0.320	12 _e	0.809	0.601	0.625	0.716	0.688
34 ₂	0.516	.473	.312	0.856	.539	12 _f	.750	.608	.582	.574	.529
34 ₃	.608		.352	.863	.604	12 _g	.587	.434	.569	.653	.561
34 ₄	.754	.434	.288		.492	12 _h			.389	.549	.469
34 ₅	.622	.542	.356	.683	.551						
3 ₁	.538	.366	.430	.523	.466	7w ₁			.626	.737	.681
3 ₂	.565	.565	.630		.587	7w ₂	.835	.550	.507	.759	.663
3 ₃	.511	.552	.364	.790	.554	7w ₃	.620	.563	.431	.782	.599
3 ₄	.693	.607	.350	.833	.621	7w ₄	.792	.777	.588	.804	.740
3 ₅	.513	.477	.533	.767	.573	7w ₅		.521	.699	.998	.739
3 ₆	.438		.392		.415	7w ₆	.674	.721	.567	.663	.656
3 ₇	.412	.415	.504		.444	7w ₇	.369	.765	.760		.631
3 ₈		.300			.300	7w ₈		.291		.645	.468
3 ₉		.479	.702	.782	.654	7w ₉	.714	.389	.544		.412
						7w ₁₀	.634	.496	.489	.764	.596
13 ₁		.255	.459	.934	.549	7w ₁₁		.404	.626	.773	.601
13 ₂		.365	.596		.481						
13 ₃			.453		.453	6w ₁	.541	.543	.501	.666	.561
13 ₄	.492	.359	.318	.649	.455	6w ₂		.693	.881		.787
13 ₅		.466	.559	.563	.529	6w ₃	.850	.641	.787	.885	.791
13 ₆			.470	.733	.601	6w ₄	.866	.516	.529	.856	.692
13 ₇		.341	.552	.766	.553	6w ₅	.806	.640	.768	.829	.761
13 ₈		.349	.664	.792	.601	6w ₆	.780	.735	.663	.733	.728
13 ₉	.566	.452	.385	.815	.555	6w ₇	.739	.917	1.131	.956	.981
						6w ₈	.780	.921	.937	1.020	.915
12 ₁	.854	.653	.737	.494	.688	6w ₉	.833	.921	.901	.919	.894
12 ₂	.480	.516	.661	.717	.594	6w ₁₀	.908	.925	.927	.876	.909
12 ₃	.760	.672	.675	.638	.686	6w ₁₁	.956	.973	.993	.924	.962
12 ₄	.605	.572	.626		.619	6w ₁₂	.681	.574	.670	.922	.712
12 ₅	.588		.675	.908	.543	6w ₁₃	1.143	.639	.852	.754	.847

SUMMARY OF ALL INDIVIDUAL PLANTS FROM EACH PARENT.

Parent plant.		Average alkaloidal content of leaves (per cent).				
No.	Yield of alkaloids.	Stage of growth.				Average for season.
		First stage.	Second stage.	Third stage.	Fourth stage.	
34	Low	0.625	0.441	0.326	0.800	0.501
3	do	.524	.470	.488	.739	.512
13	Medium	.529	.369	.495	.765	.531
12	High	.679	.573	.617	.662	.597
7w	do	.662	.547	.583	.769	.617
6w	do	.824	.740	.824	.862	.811
Average		.640	.523	.555	.766	

A careful study of Table III reveals the fact that the individual first-generation plants possess in large measure the same alkaloid-

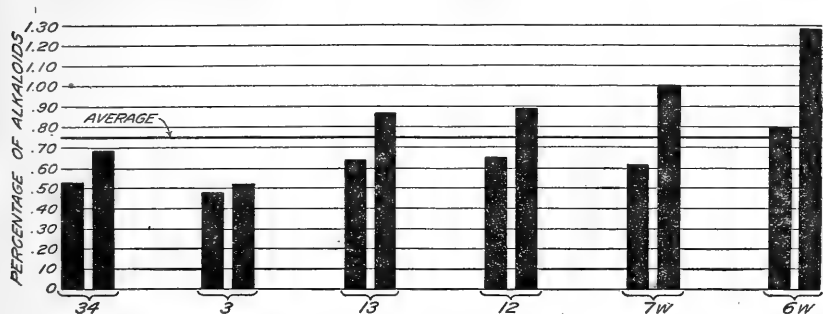


FIG. 1.—Diagram showing the alkaloidal content of the leaves of first-generation belladonna plants from cross-pollinated parents at two stages of growth during the first season, 1912. The percentages indicated represent the average of all the individuals from each parent plant.

producing characteristic as the parent plant. Plant 6w, the richest of the original 59 individual plants under observation for two years, yielded from cross-pollination first-generation plants which were distinctly rich in the first season and again in the second season. Furthermore, the plants of the first generation from the cross-pollinated individuals selected from the original list for low alkaloidal content have shown a decidedly low percentage of alkaloids during each of the two seasons of growth. Figures 1. to 4 show graphically the average percentage of alkaloids in the leaves of all the first-generation plants from each parent at each of the pickings in 1912 and 1913. Besides showing at a glance what has already been said regarding the plants which are rich or poor in alkaloids, figure 1 also shows an interesting condition with regard to the relative richness of the plants at the

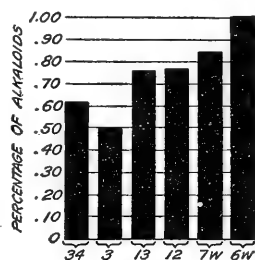


FIG. 2.—Diagram showing the average alkaloidal content of all the individual belladonna plants from each parent for the season, first year, 1912.

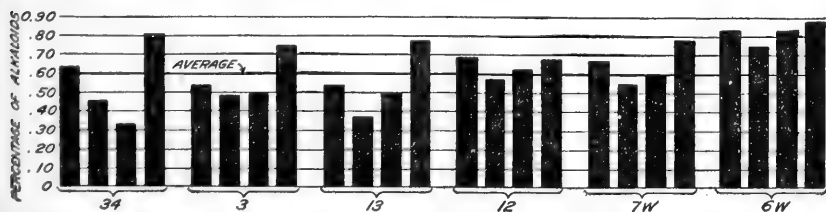


FIG. 3.—Diagram showing the alkaloidal content of the leaves of first-generation belladonna plants from cross-pollinated selected parents at four stages of growth during the first season. The percentages indicated represent the average of all the individuals from each parent plant.

various stages of growth. In the previous investigation¹ the plants were richest in alkaloids at the first and fourth stages; that is,

the stage before flowering and the stages when the berries are ripe. In another season, however, the same plants were found to be richer in alkaloids at the second and fourth stages. In the present investigation we find the greatest percentage of alkaloids at a stage of growth which corresponds to the fourth stage in the

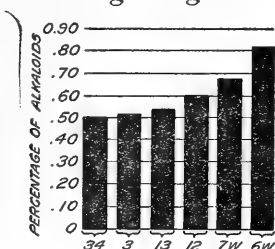


FIG. 4.—Diagram showing the average alkaloidal content of all the individual belladonna plants from each parent for the season, second year, 1913.

previous investigation. It seems, then, further established that the greatest concentration of alkaloids is at the period when the berries are mostly ripe and the leaves small and sparse.

COMPARISON OF FIRST-GENERATION PLANTS FROM CROSS-POLLINATED AND CLOSE-POLLINATED PARENTS.

From the parent plants, 6w and 7w, which yielded the progeny described in the foregoing pages, seeds were obtained in 1912 through both cross and close pollination and planted for purposes of comparison. Plants 12, 13, 3, and 34 were dead; therefore no seeds could be secured from them. In their stead, seeds were taken from plants 46 and 23, as these were examples of low alkaloid-yielding plants. The seeds were sown in the greenhouse and the seedlings transplanted to the field early in May, 1913. Owing to the hot weather and severe drought the plants made only a fair growth, and only two pickings were secured, the first on August 19, when the plants were in the flowering stage, and the second on September 23, when the berries were in various stages of ripeness. Table IV shows the percentage of alkaloids in the leaves of the individuals from each selected parent.

TABLE IV.—*Alkaloids in the leaves of first-generation belladonna plants from close pollination and cross-pollination of selected parents at two stages of growth at Arlington, Va., during the first season, 1913.*

Lot and number.	Alkaloidal content (per cent).			Lot and number.	Alkaloidal content (per cent).		
	First stage, Aug. 19.	Second stage, Sept. 23.	Average.		First stage, Aug. 19.	Second stage, Sept. 23.	Average.
Lot 6w, close pollinated:				Lot 6w, close pollinated—Contd.			
1.....	0.514	0.430	0.472	10.....	0.745	0.658	0.702
2.....	.687	.594	.640	11.....			
3.....	.421	.504	.463	12.....	.741	.705	.723
4.....	.834	.886	.860	13.....	.687	.613	.650
5.....	.773	.736	.755	14.....	.767	.750	.759
6.....	.731	.724	.728	15.....	.658	.760	.719
7.....	.689	.745	.717	16.....	.703	.722	.713
8.....	.735	.633	.684	17.....	.786	.741	.764
9.....	.696	.669	.683	18.....	.865	.515	.690

TABLE IV.—*Alkaloids in the leaves of first-generation belladonna plants from close pollination and cross-pollination of selected parents at two stages of growth at Arlington, Va., during the first season, 1913—Continued.*

Lot and number.	Alkaloidal content (per cent.).			Lot and number.	Alkaloidal content (per cent.).		
	First stage, Aug. 19.	Second stage, Sept. 23.	Average.		First stage, Aug. 19.	Second stage, Sept. 23.	Average.
Lot 6w, close pollinated—Contd.				Lot 7w, close pollinated—Contd.			
19.....	0.557	0.715	0.636	18.....	0.696	0.715	0.706
20.....		.503		19.....	.478	.669	.574
21.....	.753	.904	.829	20.....	.521		
22.....	.831	.841	.836	21.....			
23.....	.433	.562	.498	22.....	.829	.894	.862
24.....	.771	.693	.732	23.....	.574	.515	.545
25.....	.826	.789	.808	24.....	.717	.940	.829
26.....	.843	.799	.821	25.....	.813	.856	.835
27.....	.807	.657	.732	26.....	.730	.641	.686
28.....	.742	.848	.795				
29.....		.565		Average.....	.595	.632	
30.....	.794			Lot 7w, cross-pollinated:			
31.....		.662		1.....	.526	.771	.649
32.....	.690	.974	.832	2.....	.448	.468	.458
33.....	.679			3.....	.681	.586	.634
34.....	.640	.748	.694	4.....		.369	
35.....	.755	.848	.802	5.....	.512	.678	.595
36.....		.836		6.....	.813	.885	.849
37.....	.674	.526	.600	7.....	.430	.621	.526
Average.....	.672	.701		8.....	.658	.669	.664
Lot 6w, cross-pollinated:				9.....	.676	.468	.572
1.....		.724		10.....	.646	.646	.646
2.....	.609	.555	.582	11.....	.741	.631	.686
3.....		.663		12.....		.736	
4.....		.368		13.....	.598	.635	.617
5.....	.705	.683	.694	14.....		.621	
6.....	.665	.729	.697	15.....	.646	.799	.723
7.....	.557	.729	.643	16.....	.675	.526	.601
8.....	.598	.447	.523	17.....	.729	.633	.681
9.....	.504	.565	.535	18.....	.669	.609	.639
10.....	.688	.729	.709	19.....	.681	.511	.596
11.....	.759	.543	.651	20.....		.369	
12.....	.574	.574	.574	21.....	.504		
13.....	.594			22.....			
14.....	.693	.550	.622	23.....	.609		
15.....	.391			24.....	.500		
16.....	.646			Average.....	.618	.611	
17.....	.478			Lot 23, cross-pollinated:			
18.....	.486	.505	.496	1.....	.199		
19.....	.450			2.....	.369		
20.....	.621	.526	.574	3.....			
21.....	.535	.726	.681	4.....	.426		
23.....		.613		5.....	.305		
Average.....	.586	.602		6.....	.332		
Lot 7w, close pollinated:				7.....	.494		
1.....	.717	.591	.654	8.....	.538		
2.....	.645	.545	.595	9.....	.455		
3.....	.632	.515	.574	10.....	.393		
4.....		.394		Average.....	.408		
5.....	.526	.468	.497	Lot 46, cross-pollinated:			
6.....	.654	.658	.656	1.....	.383	.406	.395
7.....	.442	.492	.467	2.....	.369	.382	.376
8.....	.591	.646	.619	3.....	.451	.480	.466
9.....		.602		4.....	.314		
10.....	.409	.550	.480	5.....	.528		
11.....	.427	.470	.449	6.....	.480	.741	.611
12.....	.510	.586	.548	7.....	.400	.366	.383
13.....	.685	.753	.719	8.....	.332	.316	.324
14.....	.650	.712	.681	Average.....	.407	.448	
15.....	.340	.626	.483				
16.....	.626	.705	.666				
17.....	.492	.633	.563				

TABLE IV.—*Alkaloids in the leaves of first-generation belladonna plants from close pollination and cross-pollination of selected parents at two stages of growth at Arlington, Va., during the first season, 1913—Continued.*

SUMMARY OF AVERAGES FOR THE VARIOUS LOTS.

Lot.	Alkaloidal yield of parent.	Average alkaloidal content (per cent).		
		First stage.	Second stage.	Season.
Lot 6w, close pollinated.....	High.....	0.672	0.701	0.686
Lot 6w, cross-pollinated.....	do.....	.586	.602	.594
Lot 7w, close pollinated.....	do.....	.595	.632	.614
Lot 7w, cross-pollinated.....	do.....	.618	.611	.615
Lot 23, cross-pollinated.....	Low.....	.408	.....	.408
Lot 46, cross-pollinated.....	do.....	.407	.448	.428

The following year, 1914, these plants were again analyzed. The first picking was made on August 1, when the berries were beginning to ripen. This is the stage at which, as shown by other experiments, the greatest percentage of alkaloids is present. The second picking was made on September 5, when the berries had all ripened. Table V shows the percentage of alkaloids in each case, the averages being summarized at the close.

TABLE V.—*Alkaloids in the leaves of first-generation belladonna plants from close pollination and cross-pollination of selected parents at two stages of growth at Arlington, Va., during the second season, 1914.*

Alkaloidal content (per cent).				Alkaloidal content (per cent).			
Lot and number.	First stage, Aug. 1.	Second stage, Sept. 5.	Average.	Lot and number.	First stage, Aug. 1.	Second stage, Sept. 5.	Average.
Lot 6w, close pollinated:				Lot 6w, close pollinated—Contd.			
1.....	0.864	0.882	0.873	31.....	1.030	0.783	0.906
2.....	.770	.611	.690	32.....	.902	.792	.847
3.....	.746	.581	.663	33.....	1.031	.....	.....
4.....	.858	.858	.858	34.....	1.096	.908	1.002
5.....	.771	.829	.800	35.....	1.043	.765	.904
6.....	.761	.956	.858	36.....	.860	.657	.908
7.....	.....	.924	.....	37.....	.744	.454	.549
8.....	.924	.854	.889	Average.....	.906	.765	.....
9.....	.916	.864	.890				
10.....	.859	.618	.738	Lot 6w, cross-pollinated:			
11.....	.....	.....	.....	1.....	.....	.753	.....
12.....	1.045	.953	.999	2.....	1.169	.687	.923
13.....	.....	.831	.....	3.....	.969	.717	.843
14.....	.....	.....	.....	4.....	.....	.....	.....
15.....	.646	.693	.669	5.....	1.074	.756	.915
16.....	.....	.....	.....	6.....	.990	.575	.782
17.....	.739	.795	.767	7.....	.987	.530	.758
18.....	.943	.612	.627	8.....	.....	.....	.....
19.....	.930	.708	.819	9.....	.790	.565	.677
20.....	.681	.882	.781	10.....	.804	.663	.733
21.....	.935	.813	.874	11.....	1.062	.647	.854
22.....	1.016	.747	.881	12.....	.771	.712	.741
23.....	.....	.777	.....	13.....	.943	.626	.784
24.....	1.193	.753	.973	14.....	.903	.572	.737
25.....	.969	.837	.905	15.....	.810	.657	.733
26.....	.990	.833	.911	16.....	.....	.....	.....
27.....	1.103	.699	.856	17.....	.929	.....	.....
28.....	.976	.691	.833	18.....	.728	.621	.674
29.....	.797	.599	.698				
30.....	.941	.742	.841				

TABLE V.—*Alkaloids in the leaves of first-generation belladonna plants from close pollination and cross-pollination of selected parents at two stages of growth at Arlington, Va., during the second season, 1914—Continued.*

Lot and number.	Alkaloidal content (per cent).			Lot and number.	Alkaloidal content (per cent).		
	First stage, Aug. 1.	Second stage, Sept. 5.	Average.		First stage, Aug. 1.	Second stage, Sept. 5.	Average.
Lot 6w, cross-pollinated—Contd.				Lot 7w, cross-pollinated—Contd.			
19.....	0.997	0.520	0.758	8.....	0.816		
20.....		.559		9.....	1.062	0.596	0.579
21.....	1.124	.644	.884	10.....	.690		
22.....	1.138	.608	.873	11.....	.868		
Average.....	.952	.634		12.....	.838		
Lot 7w, close pollinated:				13.....	1.062	.574	.818
1.....	.948	.771	.859	14.....	.990	.672	.831
2.....	.626	.672	.649	15.....	.758	.425	.591
3.....	.898	.693	.795	16.....	.885	.641	.763
4.....		.777		17.....	.704	.535	.619
5.....	.704	1.098	.906	18.....	.983		.983
6.....	.953	.777	.865	19.....	.739	.394	.566
7.....	.624	.594	.609	20.....	.758	.897	.827
8.....	.851	.834	.842	21.....	1.015	.732	.873
9.....	.756	.926	.841	22.....	.784	.813	.798
10.....	.927	.822	.874	23.....	.872	.620	.746
11.....		.873		24.....	.877	.798	.838
12.....	.950	.657	.803	25.....	1.036	.823	.929
13.....	.744	.762	.753	26.....	1.036	.823	.929
14.....	1.193	.837	1.015	27.....	.631	.345	.488
15.....	.997	.599	.798	Average.....	.865	.619	
16.....	.882	.809	.845	Lot 3:			
17.....	.997	.632	.814	1.....	.452	.319	
18.....	.694	.707	.650	2.....	.452	.528	
19.....	.964			3.....	.306	.681	
20.....	.709			4.....	.425	.365	
21.....	1.010			Average.....	.409	.473	
22.....	.797			Lot 23:			
23.....	.810	.687	.748	1.....		.344	
24.....	.790	.651	.665	2.....		.472	
Average.....	.855	.753		3.....		.517	
Lot 7w, cross-pollinated:				4.....		.532	
1.....	.992	.672	.832	5.....		.448	
2.....	1.062			6.....		.581	
3.....	.864	.596	.730	7.....		.505	
4.....	.810	.523	.666	8.....		.588	
5.....	.911	.553	.732	9.....		.502	
6.....	1.036	.696	.866	10.....		.487	
7.....	.568	.463	.515	Average.....		.497	

SUMMARY OF AVERAGES FOR THE VARIOUS LOTS.

Lot.	Alkaloidal yield of parent.	Average alkaloidal content (per cent).		
		First stage.	Second stage.	Season.
Lot 6w, close pollinated.....	High.....	0.906	0.765	0.835
Lot 6w, cross-pollinated.....	do.....	.952	.634	.793
Lot 7w, close pollinated.....	do.....	.855	.753	.804
Lot 7w, cross-pollinated.....	do.....	.865	.619	.742
Lot 3, cross-pollinated.....	Low.....	.409	.473	.441
Lot 23, cross-pollinated.....	do.....		.497	.497

From Tables IV and V it becomes apparent that during both the first and second seasons these first-generation plants display very markedly the characteristic of the parents as regards alkaloid production. Thus, in 1913 the average percentage of alkaloids found in the plants from the original parent 6w and the parent 7w, which were selected for high alkaloid-producing tendencies, was 0.640 and

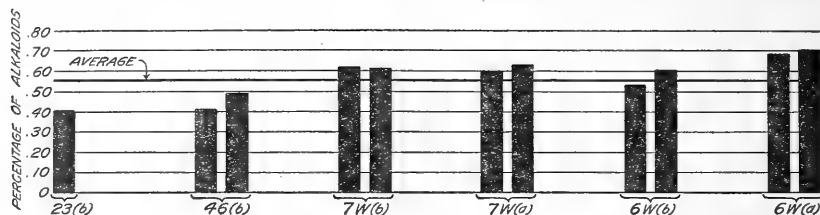


FIG. 5.—Diagram showing the alkaloidal content of the leaves of first-generation belladonna plants from close-pollinated and cross-pollinated selected parents at two stages of growth during the first season, 1913. The percentages indicated represent the average of all the individuals from each parent plant: a, Plants from close-pollinated parents; b, plants from cross-pollinated parents.

0.615 per cent, respectively. On the other hand, the averages from the plants 23 and 46, which were produced from parents of the opposite tendencies, are 0.408 and 0.428 per cent, respectively. Again the following year we find the average of plants 6w and 7w to be 0.814 and 0.773 per cent, respectively. Lot 46 was not picked that year, but lot 23 averaged 0.497 per cent.

It will be seen from the tables that the effect of close pollination as compared with cross-pollination is not as great as would be expected.

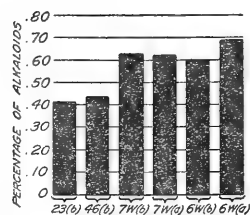


FIG. 6.—Diagram showing the average alkaloidal content of all the individual belladonna plants from each parent for the first season, 1913: a, Plants from close-pollinated parents; b, plants from cross-pollinated parents.

In the case of 6w the plants from close pollination are on the average 0.091 per cent richer than those from cross-pollination in 1913, and 0.042 per cent richer in 1914. The 7w plants show a difference of 0.001 per cent in favor of cross-pollination in 1913 and a difference of 0.062 per cent in 1914. Figures 5 to 8 graphically illustrate these conditions. Sufficient information has not been obtained to indicate with any degree of certainty the influence of cross-pollination and close pollination on the transmissibility of the alkaloid-producing characteristic. As a possible explanation of the large percentage of plants with high alkaloidal content among the first-generation plants secured from cross-pollinated selected parents, Dr. W. Van Fleet, of the Office of Drug-Plant and Poisonous-Plant Investigations, has prepared the following statement:

The arrangement of anthers and stigma in the belladonna bloom and the respective periods of their maturity and receptivity are such as to fit the plant in a high degree

for cross-pollination and to almost exclude the probability of close fertilization in individual flowers. However, the feeding habits of the principal pollinating insects (mostly night and day flying lepidoptera), which visit in turn many open blooms on the same plant, may tend after all to promote self or close pollination on a considerable proportion of blooms on any given plant. If all the seeds in a single fruit should mature and produce plants with a high alkaloidal content or any other transmissible

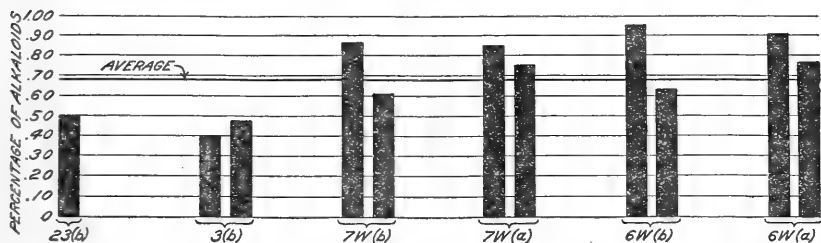


FIG. 7.—Diagram showing the alkaloidal content of the leaves of first-generation belladonna plants from close-pollinated and cross-pollinated selected parents at two stages of growth during the second season, 1914. The percentages indicated represent the average of all the individuals from each parent plant: *a*, Plants from close-pollinated parents; *b*, plants from cross-pollinated parents.

feature of the seed parent, it does not necessarily follow that the pollen of another individual possessing this feature in a lesser degree might not have a reducing effect on the desired characteristic, as the seeds planted may easily be the result of actual close pollination between different blooms of the maternal plant or even of self-fertilization of an individual bloom. It is but fair to suppose that a majority of the seeds of a given plant may thus be self-pollinated, notwithstanding nature's adaptation of the blooms for crossing, unless it has been made apparent that belladonna blooms are not receptive to their own pollen or to that of flowers on the same plant, but must be fertilized by pollen produced by another individual. This conclusion has not been demonstrated by any controlled experiments that have come to my knowledge.

SECOND-GENERATION PLANTS FROM CROSS-POLLINATION.

Up to this point the investigation has dealt entirely with first-generation plants. During the season of 1914 analyses were made of plants which represented the second generation of the original selected individuals. The seed which furnished these plants was secured from the following first-generation plants in the fall of 1913: 6W₇, 6W₁₀, 6W₁₁, 7W₅, 2₂, 2₃, 3₁, 3₈, 3₇, 34₂, 34₃, 34₄, 35₅. The plants from 6W and 7W were selected as types of high alkaloid-yielding plants, those from 2 as medium, and those from 3 and 34 as low alkaloid-yielding types. The seed was planted in the greenhouse at Arlington, Va., in January, 1914, and the plants were transferred to small pots when of suitable size.

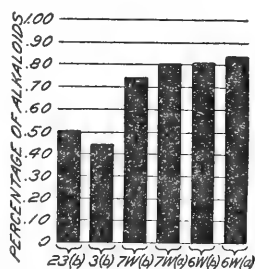


FIG. 8.—Diagram showing the average alkaloidal content of all the individual belladonna plants from each parent for the second season, 1914: *a*, Plants from close-pollinated parents; *b*, plants from cross-pollinated parents.

When the plants were about 3 inches high they were divided into three lots. One lot was transplanted to the gardens at Arlington, Va., another lot was shipped to Timmonsville, S. C., and a third lot to Madison, Wis. The object was to grow at these widely separated locations under different soil and climatic conditions plants which were obtained from a definite source. Data would thus be secured which would serve to indicate whether the transmissibility of the alkaloid-producing quality would be affected by external influences. Furthermore, it would throw some light on the question of alkaloid production as dependent on sunlight, rainfall, and soil conditions, which is a question still unsettled. At Arlington and at Madison two pickings were made of all the individuals, while at Timmonsville only one collective sample was secured from the plants from each individual parent. In Table VI the percentage of alkaloids in the individual plants at Arlington and Madison is presented, the summary of averages and the results from Timmonsville being added at the close.

TABLE VI.—*Alkaloids in the leaves of second-generation belladonna plants from cross-pollinated parents at two stages of growth at Arlington, Va., and Madison, Wis., in 1914.*

Lot and number.	Arlington, Va.			Madison, Wis.		
	First stage, Aug. 18.	Second stage, Sept. 12.	Average.	First stage, Aug. 4.	Second stage, Sept. 5.	Average.
Lot 6w ₇ :						
1.....	0.783	0.461	0.622	0.962	0.956	0.959
2.....	.542	.570	.556	.707	.813	.760
3.....		.488	.488		.781	.781
4.....	.791	.666	.728	.653	.653	.653
5.....	.414	.558	.486	.791	.530	.710
6.....		.851	.851	.765	.707	.736
7.....	.574	.620	.597	.580	.791	.685
8.....	.716	.646	.681	.599	.861	.730
9.....	.837	.835	.836	.794	.583	.688
10.....	.554	.653	.603	.478	.461	.470
11.....	.708	.522	.615	1.020	.727	.873
12.....	.674	.340	.557	1.322	1.027	1.174
13.....	.695	.605	.650	.867	.813	.840
14.....	.588	.669	.628	.956	.908	.932
15.....		.525	.525	.538	.949	.793
Lot 6w ₁₀ :						
1.....	.669	.541	.605	.736	.557	.646
2.....	.755	.691	.723	.653		.653
3.....	.639	.516	.577	.685	.829	.757
4.....				.806	.759	.783
5.....	.641	.573	.607	.822	1.068	.945
6.....	.550	.541	.546	.762	.876	.819
7.....	.748		.748	.740	.813	.776
8.....	.557		.557	.803	.733	.768
9.....				1.062	.908	.985
10.....				.695	.838	.766
11.....	.327	.398	.362	.905	1.115	1.010
12.....				.752	.813	.783
13.....				.775	.943	.859
14.....				.554	.605	.579
15.....				.806	.752	.779
Lot 6w ₁₁ :						
1.....				.554	.488	.521
2.....	.557		.557	.573		.573
3.....	.630	.636	.633	.580	.759	.669
4.....	.597	.504	.547	.781	.749	.765
5.....				.630		.630

TABLE VI.—*Alkaloids in the leaves of second-generation belladonna plants from cross-pollinated parents at two stages of growth at Arlington, Va., and Madison, Wis., in 1914—Continued.*

Lot and number.	Arlington, Va.			Madison, Wis.		
	First stage, Aug. 18.	Second stage, Sept. 12.	Average.	First stage, Aug. 4.	Second stage, Sept. 5.	Average.
Lot 6W ₁₁ —Continued.						
6.....	0.800	0.583	0.692	0.959	0.988	0.973
7.....	.840	.513	.676	.914	.908	.911
8.....		.701	.701			
9.....						
10.....		.408	.408			
11.....	.359	.541	.450			
12.....						
13.....		.392	.392			
14.....	.574	.775	.679			
15.....						
16.....		.488	.488			
17.....	.587	.433	.510			
18.....	.526	.318	.422			
Lot 7W ₃ :						
1.....	.653	.653	.653	.521	.560	.551
2.....	.659	.557	.608	.513	.484	.498
3.....	.543		.543			
4.....	.554	.541	.548			
Lot 2 ₂ :						
1.....	.545		.545	.580	.775	.677
2.....	.365	.408	.386	1.170	1.221	1.196
3.....	.369	.494	.431	.864	.723	.794
4.....	.310	.478	.394	.765	.617	.691
5.....		.295	.295		.605	.605
6.....	.557	.513	.535	.642	1.099	.870
7.....		.324	.324			
8.....	.426	.337	.382			
Lot 2 ₃ :						
1.....				.461	.669	.568
2.....				.478	1.086	.782
3.....	.573	.547	.560	.573	1.250	.911
4.....				.620	.535	.577
5.....	.423	.372	.397	.870	1.309	.589
6.....		.382	.382	.625	.972	.799
7.....	.489	.646	.567	.478	.924	.701
8.....				.532	.679	.605
9.....	.536	.532	.534	.478	.781	.629
10.....	.462	.455	.459	.491	.636	.564
11.....	.418	.538	.478	.455	.691	.573
12.....		.382	.382	.510	.924	.717
13.....	.511	.420	.465	.494	.599	.547
14.....	.519	.442	.482		.892	.892
15.....	.420	.567	.494	.630	.723	.676
16.....	.456	.525	.492	.324	.366	.345
17.....	.510	.318	.414			
Lot 3 ₁ :						
1.....				.474	.617	.546
2.....	.532		.532	.318	.669	.493
3.....				.312	.423	.367
4.....	.522	.510	.516	.350	.510	.430
5.....				.504	.803	.654
6.....	.197		.197	.541	.852	.697
7.....	.433	.263	.348	.445	.510	.417
8.....						
Lot 3 ₂ :						
1.....		.292	.292	.350	.424	.387
2.....				.484	.502	.493
3.....					.682	.682
Lot 3 ₃ :						
1.....	.457	.350	.403	.488		.488
2.....	.502	.324	.413	.717	.978	.847
3.....	.412	.334	.373	.494	.539	.516
4.....	.420	.414	.417	.573	.630	.601
5.....				.653		.653
6.....	.411	.408	.426	.717	.813	.765
7.....	.418	.636	.512	.488	.672	.580
8.....	.463	.455	.459		.701	.701
9.....	.452	.550	.501			
10.....	.421	.318	.369			

TABLE VI.—*Alkaloids in the leaves of second-generation belladonna plants from cross-pollinated parents at two stages of growth at Arlington, Va., and Madison, Wis., in 1914—Continued.*

Lot and number.	Arlington, Va.			Madison, Wis.		
	First stage, Aug. 18.	Second stage, Sept. 12.	Average.	First stage, Aug. 4.	Second stage, Sept. 5.	Average.
Lot 34 ₂ :						
1.....	0.621	.....	0.621	0.940	0.707	0.823
2.....	.....	.....	.....	.729	.646	.687
3.....	.630	.....	.630	.822	.....	.822
4.....	.646	.....	.646	.478	.439	.458
5.....	.....	.....	.....	.797	.605	.701
6.....	.....	.....	.....	.663	.445	.554
7.....	.440	0.350	.395	.605	.510	.558
8.....	.562	.376	.479	.756	.845	.800
9.....	.369	.366	.368	.636	.669	.652
10.....	.430	.254	.342	.717	.749	.733
11.....	.459	.382	.421	.710	.886	.798
12.....	.507	.343	.425	.797	.541	.669
13.....	.483	.461	.472	.714	.663	.689
14.....	.521	.....	.521	.599	.797	.698
15.....	.720	.626	.673	.685	.876	.782
16.....	.550	.461	.505	.302	.701	.501
17.....	.618	.324	.471	.....	.491	.491
18.....	.511	.382	.447	.....	.....	.....
Lot 34 ₃ :						
1.....	.....	.546	.546	.596	.832	.714
2.....	.659	.589	.624	.532	.765	.648
3.....	.650	.501	.576	.573	.791	.682
4.....	.626	.580	.603	.....	.876	.876
5.....	.....	.....	.....	.559	.803	.681
6.....	.....	.....	.....	.593	.861	.727
Lot 34 ₄ :						
1.....	.482	.356	.419	.414	.681	.547
2.....	.641	.....	.641	.350	.752	.556
3.....	.503	.504	.504	.350	.532	.441
4.....	.450	.142	.296	.398	.508	.453
5.....	.489	.458	.474	.461	.....	.461
6.....	.515	.593	.554	.471	.478	.475
7.....	.....	.....	.....	.....	.699	.699
8.....	.517	.330	.424	.346	.792	.569
9.....	.....	.....	.....	.359	.732	.596
10.....	.512	.494	.503	.455	.756	.605
11.....	.458	.438	.458	.....	.....	.....
12.....	.....	.....	.....	.....	.....	.....
13.....	.398	.....	.398	.....	.....	.....
Lot 34 ₅ :						
1.....	.....	.461	.461	.398	.414	.406
2.....	.....	.....	.....	.445	.541	.493
3.....	.558	.445	.501	.484	.605	.545
4.....	.....	.458	.458	.414	.541	.478
5.....	.....	.343	.343	.....	.478	.478
6.....	.....	.478	.478	.541	.911	.726
7.....	.421	.445	.433	.392	.956	.674
8.....	.....	.318	.318	.583	.573	.578
9.....	.....	.....	.....	.....	.350	.350
10.....	.....	.....	.....	.414	.468	.441
11.....	.....	.....	.....	.....	.318	.318
12.....	.....	.....	.....	.....	.....	.....
13.....	.....	.....	.....	.....	.....	.....
14.....	.674	.532	.603	.....	.....	.....
15.....	.263	.308	.286	.....	.....	.....

TABLE VI.—*Alkaloids in the leaves of second-generation belladonna plants from cross-pollinated parents at two stages of growth at Arlington, Va., and Madison, Wis., in 1914—Continued.*

SUMMARY OF AVERAGES FOR EACH LOT, INCLUDING RESULTS AT TIMMONSVILLE, S. C.

Lot.	Alkaloidal content (per cent).							
	Arlington, Va.			Madison, Wis.			Timmons ville, S. C.	
	First stage, Aug. 18.	Second stage, Sept. 12.	Average.	First stage, Aug. 4.	Second stage, Sept. 5.	Average.	First stage.	Average.
Lot 6w ₇	0.656	0.600	.....	0.783	0.777	.....	0.992	.....
Lot 6w ₁₀	.611	.543	.....	.800	.829	.....	.906	.....
Lot 6w ₁₁	.608	.524	.....	.729	.745	.....	.849	.....
Average.....	.625	.556	0.592	.771	.784	0.778	.916	0.916
Lot 7w ₅	.602	.584	.593	.524	.532	.528	.950	.950
Lot 2 ₂	.429	.407	.....	.822	.840	.....	.....	.....
Lot 2 ₃	.483	.471	.....	.674	.814	.....	.771	.....
Average.....	.456	.436	.446	.748	.827	.788	.771	.771
Lot 34 ₂	.538	.384	.....	.673	.661	.....	.801	.....
Lot 34 ₃	.645	.554	.....	.696	.821	.....	.852	.....
Lot 34 ₄	.496	.414	.....	.530	.660	.....	.663	.....
Lot 34 ₅	.479	.421	.....	.514	.569	.....	.705	.....
Average.....	.539	.443	.491	.603	.678	.642	.755	.755
Lot 3 ₁	.496	.386	.....	.524	.627	.....	.702	.....
Lot 3 ₆.....	.....	.....	.....	.476	.536	.....	.532	.....
Lot 3 ₇	.446	.421	.....	.602	.722	.....	.669	.....
Average.....	.471	.402	.437	.534	.628	.581	.634	.634

A study of Table VI will reveal the fact that the plants showed marked differences in the percentage of alkaloids produced at the different stations. Thus, the general season average of all the plants at Arlington was 0.512 per cent, at Madison 0.663 per cent, and at Timmons ville 0.804 per cent. At the last-mentioned station, however, only one picking was made, which may account in some measure for the unusually high percentage of alkaloids found. At Arlington the first picking assayed considerably higher than the second, while at Madison the second picking was richer. It should be remembered, however, in this connection, that the season at Madison is somewhat later than at Arlington. Previous experiments have shown that the plants are richest in alkaloids when the flowering period is over and the berries are beginning to ripen. At this stage the leaves are small but very rich in alkaloids. At Arlington the first picking was made August 18, when the plants were in the stage just described, and the second picking was made later in the season, when the new growth had reduced the percentage of alkaloids considerably. At Madison, on the other hand, the first picking was made August 4, before the

rich stage was reached, and consequently the second picking, September 5, corresponds very closely to the first picking at Arlington

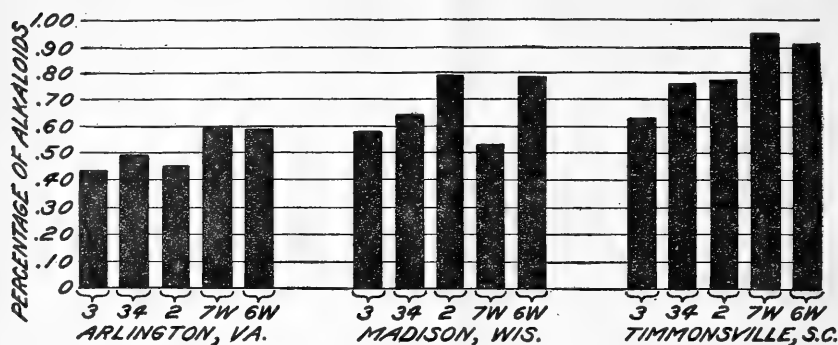


FIG. 9.—Diagram showing the alkaloidal content of the leaves of second-generation belladonna plants from cross-pollinated parents at two stages of growth at Arlington, Va., and Madison, Wis., and at one stage of growth at Timmons ville, S. C., during the first season, 1914.

in so far as the stage of growth is concerned. It is evident from the results obtained that at all three stations these second-generation

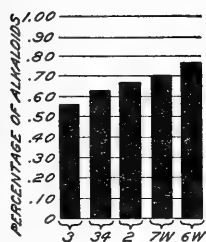


FIG. 10.—Diagram showing the average alkaloidal content of all the individual second-generation belladonna plants from each parent at Arlington, Va., Madison, Wis., and Timmons ville, S. C., during the first season, 1914.

plants show the characteristics of the parents as regards their alkaloidal content. Naturally, there are individual variations, and the plants at one station may be uniformly lower in alkaloidal content than at another station, but the point to be observed here is that at all the stations it is true in a general way that the plants selected originally from parents of high alkaloid-yielding tendencies show generally a greater percentage of alkaloids than those from parents of the opposite tendency. Table VI and figures 9 and 10 show this very plainly. It must be pointed out, however, that only a few plants were included under lot 7W₅, and this must be borne in mind when studying the averages.

In order to gather some information regarding the influence of climatic conditions upon alkaloid production, a tabulation was made of the principal weather characteristics at or near the three stations for the four months, May to August, inclusive, of the year 1914. This compilation is shown in Table VII.

TABLE VII.—*Temperature, precipitation, and days of sunshine at Arlington, Va., Madison, Wis., and Timmons ville, S. C., during May, June, July, and August, 1914.*

Station and month.	Temperature (° F.).			Precipitation.			Aspect of sky (days).*		
	Mean maximum.	Mean minimum.	Mean.	Total.	Departure from normal.	Days with 0.01 or more.	Clear.	Partly cloudy.	Cloudy.
Washington, D. C.: ¹				<i>Inches.</i>	<i>Inches.</i>				
May.....	78	55	67	1.72	-2.1	7	14	11	6
June.....	84	64	73.8	6.20	2	11	12	12	6
July.....	85	67	75.9	2.32	-2.3	12	7	12	12
August.....	86	66	76.4	6.00	1.6	10	10	13	8
Total.....				16.24			43	48	32
Florence, S. C.: ²									
May.....	87.2	57.4	72.3	1.70		2	14	13	4
June.....	92.1	68.9	80.5	3.88		7	12	12	6
July.....	92.8	68.5	80.6	3.31		6	12	16	3
August.....	89.9	69.3	79.6	4.19		10	8	15	8
Total.....				13.08			46	56	21
Madison, Wis.:									
May.....	69.7	50.9	60.3	5.97	2.35	13	9	14	8
June.....	75.7	57.6	66.6	3.46	-0.64	14	8	12	10
July.....	83	64.6	73.8	1.49	-2.50	8	13	13	5
August.....	79.6	61	62.5	3.60	.39	7	11	12	8
Total.....				14.52			41	51	31

¹ The conditions at Washington should approximate very closely those at Arlington, Va.² About 7 miles from Timmons ville, S. C.; volunteer observer.

It has been claimed by some investigators that dry and sunny seasons will result in greater alkaloid production than wet and cloudy seasons. The data in Table VII will serve to throw some light on this point. The plants from the three localities specified were all grown from the same seed, and it would appear that if the contention regarding climate were correct there should be some correlation between the quantity of alkaloids found and the seasonal conditions. However, in the four months there is a difference of only about 3 inches in the rainfall and a difference of only five in the number of sunny days. It is true that at Timmons ville the precipitation was the least and the number of sunny days the greatest, and the percentage of alkaloids was also the greatest. It has already been pointed out, however, that only one picking of leaves was secured at this place, which may account for the high average percentage of alkaloids found; and, furthermore, the difference in climatic conditions is so small that little significance can be attached to it. It is possible, of course, that differences in soil conditions at the three stations may be sufficiently great to influence any relationship due to climatic conditions which might otherwise be apparent.

REPRODUCTION OF SELECTED PLANTS FROM CUTTINGS.

In the fall of 1913 cuttings were secured from the first-generation plants and rooted in the greenhouse. Although the season had been bad and the condition of the cuttings was rather poor, a good percentage of them rooted and by spring furnished plants 3 to 4 inches high. These were transplanted to the field early in May. The severe drought during that month caused a considerable number of the plants to die, although they had developed a good root system. On August 18, when the flowering was mostly over, the first picking was made. On October 12, after most of the berries were ripe and some new leaves had developed, a second picking was secured. In Table VIII are given the percentages of alkaloids found in each individual plant, the summary of seasonal averages being added at the close.

TABLE VIII.—*Alkaloids, at two different stages, in the leaves of belladonna plants grown from cuttings from selected parents at Arlington, Va.*

Lot and number.	Alkaloidal content (per cent).			Lot and number.	Alkaloidal content (per cent).		
	First stage, Aug. 18.	Second stage, Oct. 12.	Average for season.		First stage, Aug. 18.	Second stage, Oct. 12.	Average for season.
Lot 6w ₁ :				Lot 6w ₁₁ —Contd.			
5.....	0.573	0.491	0.532	9.....	0.602	0.613	0.608
Lot 6w ₂ :				11.....	.871	.669	.770
2.....	.512	.525	.517	12.....	.801	.829	.815
Lot 6w ₃ :				13.....	.680	.420	.550
1.....		.525	.525	15.....		.630	.630
2.....	.725	.593	.659	16.....	.510	.238	.374
3.....		.496	.496	17.....		.537	.537
4.....	.606	.620	.613	19.....	.665		
5.....	.604	.488	.546	Average.....	.687	.611	.649
6.....	.837	.749	.493				
Average.....	.693	.578	.634	Lot 6w ₁₂ :			
Lot 6w ₄ :				2.....	.624	.610	.617
1.....	.573	.522	.548	3.....	.731	.398	.565
2.....	.615	.580	.597	4.....		.445	.445
3.....	.585	.343	.464	Average.....	.677	.484	.581
4.....	.607	.478	.543				
5.....		.589	.589	Lot 7w ₃ :			
5.....		.315	.315	2.....	.477	.429	.453
7.....	.573	.442	.508	5.....		.794	.794
8.....	.516	.372	.444	Average.....	.477	.611	.544
Average.....	.575	.455	.565				
Lot 6w ₅ :				Lot 7w ₄ :			
1.....	.795	.797	.796	1.....	.587	.567	.577
2.....	.745	.749	.747	2.....		.557	.557
Average.....	.770	.773	.772	3.....	.562	.525	.544
Lot 6w ₉ :				5.....	.631	.666	.648
6.....	.770	.516	.643	6.....			
Lot 6w ₁₀ :				7.....	.436	.669	.553
1.....	.623	.618	.621	Average.....	.553	.597	.575
3.....	.660	.691	.676				
Average.....	.641	.654	.648	Lot 7w ₅ :			
Lot 6w ₁₁ :				1.....		.569	.569
1.....	.774	.653	.714	2.....		.636	.636
2.....	.602		.602	4.....	.584	.784	.684
5.....	.598		.598	5.....	.837	.759	.798
6.....	.682	.752	.717	6.....	.734	.620	.677
8.....	.661	.775	.718	7.....	.639	.700	.669
				8.....	.657	.578	.668
				Average.....	.690	.664	.677

TABLE VIII.—*Alkaloids, at two different stages, in the leaves of belladonna plants grown from cuttings from selected parents at Arlington, Va.—Continued.*

Lot and number.	Alkaloidal content (per cent).			Lot and number.	Alkaloidal content (per cent).		
	First stage, Aug. 18.	Second stage, Oct. 12.	Average for season.		First stage, Aug. 18.	Second stage, Oct. 12.	Average for season.
Lot 7w ₁₀ :				Lot 34 ₃ :			
3.....	.516	.688	.602	1.....	0.623		0.623
6.....		.864	.864	2.....	.539	0.596	.567
Average.....	.516	.776	.646	Average.....	.581	.596	.588
Lot 34 ₂ :				Lot 34 ₅ :			
1.....		.636	.636	1.....	.514	.439	.476
3.....	.499	.391	.445	2.....	.458	.440	.449
4.....	.598	.525	.562	Average.....	.486	.440	.463
5.....	.558	.408	.483				
6.....	.601	.590	.596				
Average.....	.564	.510	.537				

SUMMARY OF SEASONAL AND GROUP AVERAGES.

Lot.	Alkaloid yield of parent.	Average alkaloidal content (per cent).	
		For season.	For all plants from same parent.
Lot 6w ₁	High.....	0.532	0.616
Lot 6w ₂	do.....	.517	
Lot 6w ₃	do.....	.634	
Lot 6w ₄	do.....	.565	
Lot 6w ₅	do.....	.772	
Lot 6w ₉	do.....	.643	
Lot 6w ₁₀	do.....	.648	
Lot 6w ₁₁	do.....	.649	0.610
Lot 6w ₁₂	do.....	.581	
Lot 7w ₂	do.....	.544	
Lot 7w ₄	do.....	.575	
Lot 7w ₅	do.....	.677	0.529
Lot 7w ₁₀	do.....	.646	
Lot 34 ₂	Low.....	.537	0.529
Lot 34 ₃	do.....	.588	
Lot 34 ₅	do.....	.463	

Here, again, the plants from lots 6w and 7w show marked superiority over those of lot 34, the parent plant of which was poor in alkaloids. These plants will be observed and studied carefully through another season, to determine whether the same relationship holds true, after which desired individuals will be selected and further propagated through cuttings.

CONCLUSIONS.

It having been established in the previous investigation that a wide range of variation exists in the alkaloidal content of belladonna plants, the present investigation was undertaken to determine whether the characteristic of alkaloid production is transmissible to

the progeny through seed and whether the character is changed by vegetative propagation. The results thus far show that the first-generation plants secured from seed of cross-pollinated selected individuals display the characteristic of the maternal parent with regard to alkaloid productivity. This condition is generally true at all stages of growth during a season and also for at least two successive seasons. Close pollination of the parent plant has shown only a moderate influence on the transmission of this characteristic.

Second-generation plants from cross-pollination have been grown at Arlington, Va., Madison, Wis., and Timmonsville, S. C., and at all three stations they have displayed the relative alkaloid-producing tendencies evident in the original parent plant and the generation preceding.

While the plants at the different localities showed a parallel relationship toward each other, there was considerable difference in the general quantity of alkaloids produced. Thus, in the case of Madison and Arlington, where two pickings were made at fairly corresponding stages of growth, it was found that the Madison plants yielded more alkaloids than those at Arlington. At Timmonsville the yield was still greater than at Madison, but here only one picking was made, and it is hardly possible to make a true comparison. Nothing definite developed to indicate that a relationship exists between the amount of precipitation and sunshine and the percentage of alkaloids produced.

Plants were grown from cuttings, and at two stages of their growth these plants showed a marked tendency to display the same characteristic regarding alkaloid production as the plants from which they were propagated and the original parents of those plants.

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WM. A. TAYLOR, Chief



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PROFESSIONAL PAPER

December 14, 1915

TESTS OF CORN VARIETIES ON THE GREAT PLAINS.

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INTRODUCTION.

This bulletin contains results of varietal tests conducted on dry land and under irrigation at several stations ¹ in the Great Plains area. These tests have been conducted for the purpose of studying the possibilities of the region for corn production, to study in what ways the climatic influences would affect different varieties and seed from different localities, and to determine what varieties might offer the best possibilities for further improvement and adaptation to the region.

The tests have not been conducted for a sufficient length of time to make the results conclusive. They have, however, furnished information regarding varietal differences which is thought to be of sufficient interest to warrant publication at this time.

NATURAL LIMITATIONS TO CORN PRODUCTION.

The chief limitation to corn production on the Great Plains is that of climate. This area is characterized by scant and uncertain precipitation and short, variable growing seasons. The effects of these

¹ These tests have been conducted by the Office of Corn Investigations at Huntley, Mont., Newell, S. Dak., and Mitchell, Nebr., in cooperation with the Office of Western Irrigation Agriculture; at North Platte, Nebr., in cooperation with the Nebraska Experiment Substation; and at Akron, Colo., in cooperation with the Office of Dry-Land Agriculture. At the first two stations mentioned the work has been for the most part conducted by Dan Hansen and Beyer Aune, farm superintendents. At the other stations assistance has been rendered by Fritz Knorr, V. V. Burr, and O. J. Grace.

NOTE. This bulletin is of particular interest to farmers, investigators, and teachers in the Great Plains area.

influences vary in amount from only slight injury to total crop failure and in extent from restricted localities to extended areas. A year seldom occurs in which as a result of these influences there is not some restriction to the growth and development of the corn plant. In favorable seasons and localities good yields are frequently obtained, but efforts to

grow corn for grain with the natural rainfall of this area have often resulted in partial or total crop failures. It is to be expected that the same conditions and results will in a large measure continue to occur.

In those localities where it has been possible to supplement the natural rainfall with irrigation, corn is raised with considerable success. Failures which at first occurred on account of carelessness and the unintelligent use of water and from attempting to grow varieties not adapted to the locality are being corrected as knowledge is gained from experience.

The part of the Great Plains area best adapted to corn production is the north-central section.

(Fig. 1.) In this section,

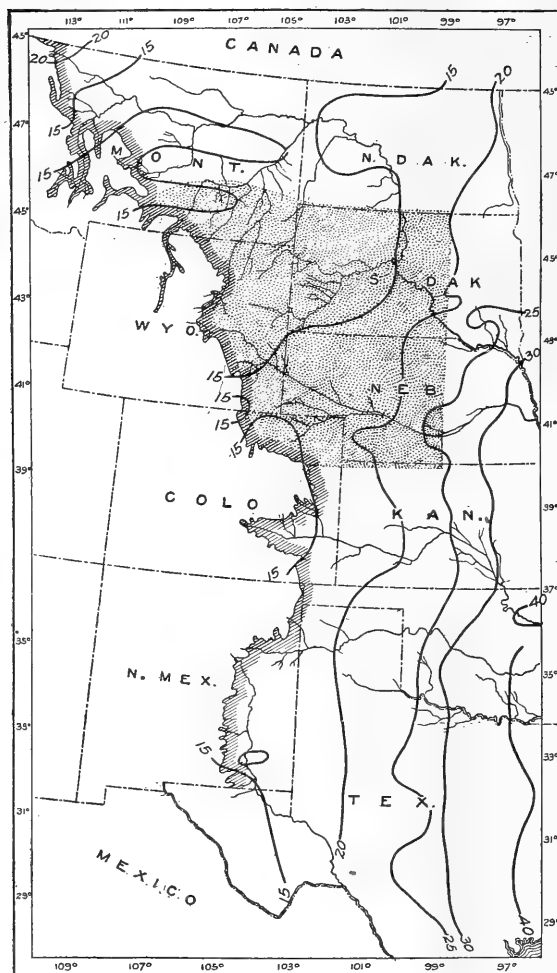


FIG. 1.—Sketch map of the Great Plains area, showing the annual rainfall (heavy black lines) and the region (dotted section) to which the varietal adaptations of corn discussed in this bulletin apply.

notwithstanding the frequent failures of corn to produce grain, the area devoted to its production has increased until corn is one of the most generally and widely grown crops. Corn is less successful in the southern Plains area, as drought injury is more severe, on account of the higher evaporation rate. Corn does not successfully compete in production with the grain sorghums under these conditions, and

the quality of the crop produced is usually poor, owing to earworm injury.

In the most northern sections and in the high altitudes along the western border, the short season prevents the growing of any except very early varieties of corn, and these reach full maturity only in favorable years.

ADAPTABILITY OF VARIETIES.

Not much attention has been given to seed selection and improvement in this area. Established varieties are few, and seed shortages are frequently caused by crop failures. These conditions create a need for information as to what may be expected from different kinds of seed.

The following descriptive list of varieties and results of trials reported calls attention to differences which have been found to exist between the varieties grown and indicates in a general way what may be expected from them in different localities.

This list includes varieties which have been grown in at least two trials made by the Department of Agriculture in the Plains area. Many other varieties are adapted to and grown in this area. For various localities some of these may be superior to any varieties included in this list.

A great variety of colors is found among dent, flint, and soft corns. Among flint corns white and yellow colors predominate, while among flour corns blue and mixed colors are of more frequent occurrence.

Dent, flint, and soft varieties of corn are listed separately, and a brief introductory description is given of the importance and peculiarities of each class.

DENT VARIETIES.

The dent corns are more extensively grown in the Plains area than are the flint and flour or soft corns. A considerable diversity of type exists between varieties, and within many so-called varieties almost as great diversity exists as between varieties. In dent corns, which have been grown in this section for some time, there is a tendency toward flintiness or hardness of texture. Whether this is due to mixing with flint corns or to a natural effect of the adverse climatic conditions has not been determined. A greater tendency to sucker is also evident among these corns than among the dent corns of the corn-belt States. This is probably due both to the lack of selection to suppress the tendency and to the stimulus of favorable conditions in the early stages of growth. In much of this region the soils are fertile and usually in good physical condition in the spring. They are light enough in texture to warm up readily and usually contain sufficient and seldom an excess of moisture. These conditions favor a rapid early growth, which is usually accompanied by profuse suckering.

The discussion of adaptations of varieties given in the following list applies only to that section of the north-central Plains shown as a dotted area in figure 1:

U. S. Selection 160.—Kernels light yellow; depth medium shallow; hard, and but slightly dented; cob white; ear surface smooth. Seed secured from central California. This variety is not adapted to this section.

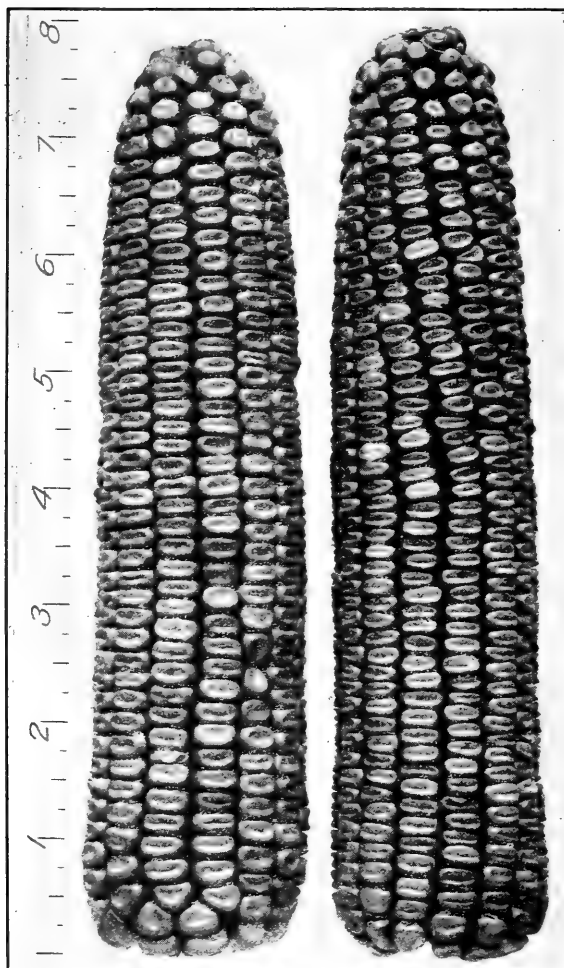


FIG. 2.—Ears of corn of U. S. Selection 133.

used as a standard for the variety tests conducted at North Platte and has been outyielded there in but few instances. It will mature in the southeastern part of this section.

(b) *Mitchell Calico.*—Similar to North Platte Calico except that it is about 10 days earlier in maturity and suckers somewhat more. This corn has been grown under irrigation for several years on the Scottsbluff, Nebr., Experiment Farm. It is adapted to similar conditions.

Silver King, or Wisconsin 7.—Kernels white, medium to deep, inclined to starchiness; cob white; ear surface rough. Seed secured from Wisconsin. Will mature in the southeastern part of this territory.

Calico.—The corns of this name are extensively grown in this section. There are many variations in color, hardness, size and shape of ear, and length of time required to mature. All are characterized by red stripes on the seed coat or hull of the kernel, but the color associated with this may be either white or yellow. Mixed cob colors predominate, but white and red cobs occur. Two strains are given below.

(a) *North Platte Calico.*—Kernel color medium; depth medium to shallow; somewhat flinty; surface, medium to smooth. Grown at North Platte Experiment Substation for several years, where some attention has been given to its selection to reduce sucker production and to increase yield.

This corn has been

Minnesota 13.—Kernels yellow, depth medium to shallow; cob red. Seed secured from Minnesota. This corn is grown over a wide range of territory in the North-Central States, and seed secured from different sections requires different seasons to mature. Average seed will mature in the southeastern half of this territory.

U. S. Selection 133.—Kernels yellow, depth medium; cob red; ear surface medium smooth. Seed secured from Wisconsin. Will mature in the greater part of this territory. This corn has occupied a high rank for yield in all tests in which it has been included, frequently outyielding seed grown in the vicinity of the tests. Typical ears are shown in figure 2.

Golden Glow.—Kernels yellow, depth medium; cob red; ear surface medium. Seed secured from Wisconsin. Will mature only in the southern half of this territory in favorable seasons and locations.

Colorado Early Select.—Kernels yellow, depth medium; cob red; ear surface medium. Seed secured from eastern Colorado. Too late in maturing for most of this territory.

Ninety-Day Disco.—Kernels white, depth medium; cob white; ear surface medium. Seed secured from southeastern South Dakota. Will mature in the southern part of this territory.

Swadley.—Kernel color white-capped yellow, depth rather shallow; cobs red; ear surface usually smooth. Variable in type. Seed secured from Washington County, Colo. Quite commonly grown and popularly regarded as being adapted to dry-land conditions. It will mature in about the southern half of this territory.

Ardmore Yellow. Kernels yellow, shallow, and broad; cobs mostly white; ear surface smooth; usually eight rows of kernels on the ear; variable in type; stalks short and ears borne close to ground; suckers profusely. Seed secured from southwestern South Dakota. This corn is very early and will mature in any part of this territory. It usually produces some grain even in severe years, but yields less than larger varieties in favorable years and localities.

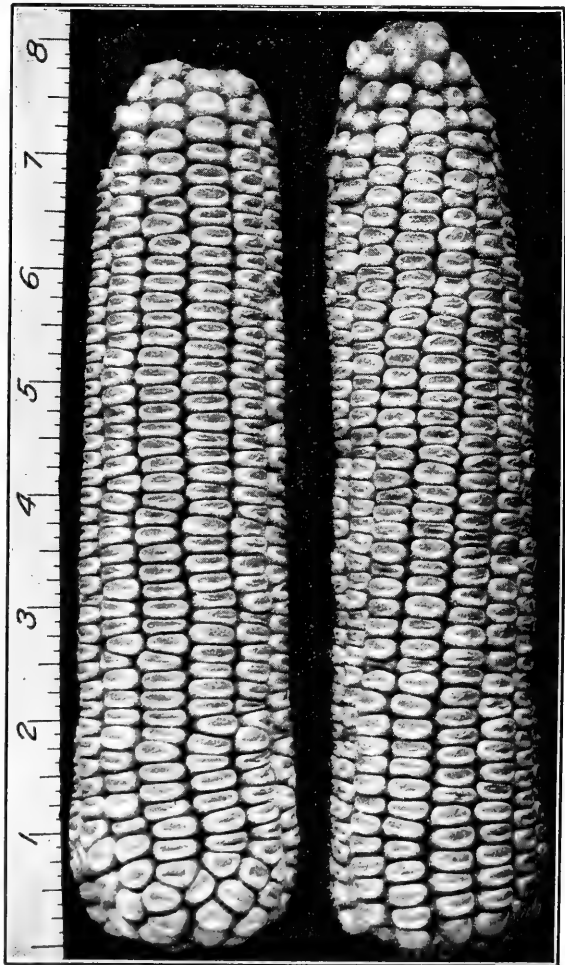


FIG. 3.—Ears of Martens White Dent corn.

Martens White Dent.—Kernels white with some yellow mixture, depth medium to shallow; cob white; ear surface medium; quite variable in type. Seed secured from northwestern Nebraska, where it has been grown without irrigation for a

number of years. It has occupied a high rank for yield in a number of tests and seems to be a very hardy, early-maturing corn. It will mature in all of this territory except in localities of shortest season and in seasons when very early frosts occur. Typical ears are shown in figure 3.

Brown County Yellow.—

Kernels yellow, small; cobs red; ear surface medium to rough. Seed secured from eastern South Dakota. This is a very early, hardy corn and will mature in any part of this territory. Under favorable conditions it will not produce as heavily as some of the larger and later varieties.

Northwestern Dent.—Kernels red with light-colored caps; cobs white; ear surface medium to smooth; stalks short; produces many suckers. Seed secured from central North Dakota. Seed from different localities varies greatly in time required to mature. Average seed will mature in almost any part of this territory. Particularly adapted to localities having short growing seasons.

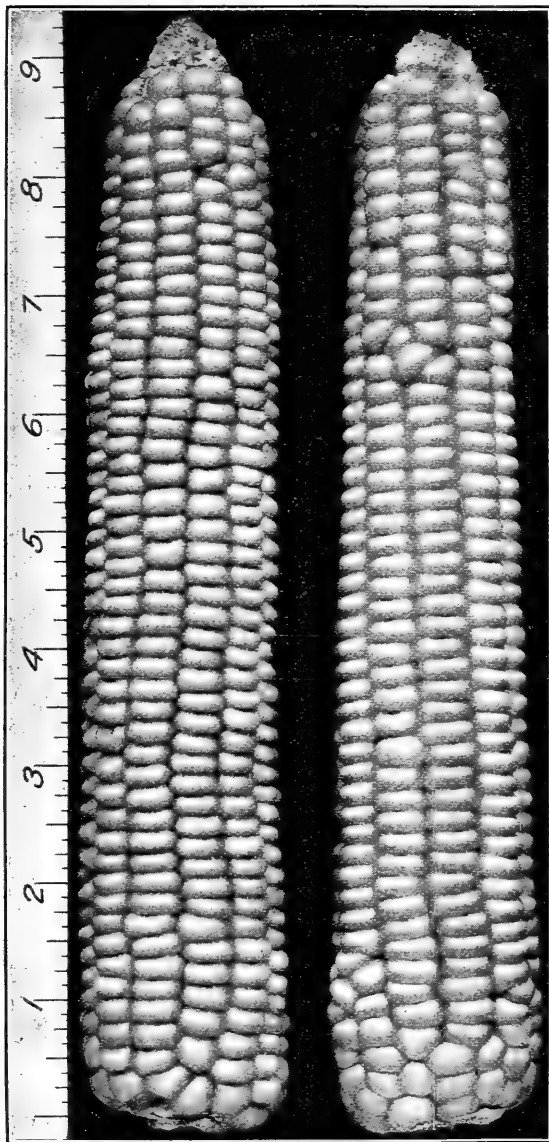


FIG. 4.—Ears of White Australian corn.

Minnesota 23.—Kernels yellow with white caps, depth medium to shallow; cobs red; ear surface medium to smooth; stalks small with few suckers. Seed secured from Minnesota. This corn is among the very early dent varieties.

Payne White Dent.—Kernels white, depth medium to shallow; cobs white. Seed secured from eastern South Dakota. Will mature in the southeastern half of this territory.

FLINT VARIETIES.

In most of this territory the flint corns are less popular and less extensively grown than the dent corns. Their objectionable features are the hardness of the grain when fully mature and the difficulty of husking. The flint corns are regarded as being very hardy and under adverse conditions frequently outyield dent corns. The flint corns sucker profusely and respond to favorable conditions by producing ears on suckers and by producing more than one ear to the stalk.

If fed before becoming fully mature and under conditions where it is possible to harvest the crop with live stock, some of the flint corns may exceed dent varieties in profitable production.

White Australian.—Kernel color dull white; very hard; ears smooth and with 10 to 14 rows of kernels. Seed secured from eastern Colorado. Of the flint varieties this corn is that most generally grown in this territory. It will mature in nearly all localities. In all tests in which it has been included it has compared well in yield with the best flint and dent varieties. Typical ears are shown in figure 4.

Cassia County Flint.—Similar to White Australian. The two varieties are probably of the same origin. Seed secured from southern Idaho.

Gehu Flint.—Kernels light yellow, small, and very hard; cob white; ears small and smooth; stalks small and ears borne very close to ground. Seed secured from central North Dakota. This corn is one of the very earliest grown in the United States and will safely mature in any part of this territory.

Amber Flint.—Kernel color amber; ears medium size. Seed secured from eastern South Dakota. Will mature in the southeastern part of this territory.

SOFT OR FLOUR VARIETIES.

The soft or so-called flour or squaw corns are grown to a somewhat less extent than the flints in this territory. In appearance, character of plants, and habits of growth they are very similar to the flint corns. As the name implies, they are soft in texture. The mature corn is more easily eaten by live stock than flint corn, but it is probably somewhat inferior in feeding value.

Between the true flint and flour types there are all gradations in texture.

Mitchell Blue Flour.—Kernels blue, with some white mixture; has a slight flintiness; cob white; small stalks with ears close to ground. Seed secured from extreme west-central Nebraska. Will mature in any part of this territory.

Dakota Red Squaw.—Color dark red; has a slight flintiness; cobs white. Seed secured from eastern South Dakota. This corn matures in the southern half of this territory and has given fair yields where tried.

TIME REQUIRED FOR MATURITY.

The time required for any variety of corn to reach maturity depends largely upon the conditions of temperature, sunshine, and moisture of the locality where grown. The performance of a variety in one locality can not, therefore, be taken as an indication, except in a general way, of the time required by that variety to mature in other localities where conditions of growth are different. Under like

conditions, however, different varieties are affected in much the same way; that is, differences between early and late varieties are in a measure retained, whether maturity is delayed or hastened by growing conditions.

The varieties previously described are arranged in Table I in their approximate order of earliness, as nearly as this could be judged from all the tests conducted. The earliest varieties are placed first and the latest varieties last in the table. The extreme range in time of maturity is about 25 days. The earliest varieties require under average conditions from 75 to 85 days, while the latest ones require from 100 to 110 days to mature.

For convenience of reference the varieties are divided into three classes, designated as very early, early, and comparatively late. There is a marked difference in the average time of maturity of these classes, but the lines between classes are necessarily somewhat arbitrary; that is, the differences between the last varieties in one class and the first varieties in the next class are not greater than the difference between varieties of the same class.

TABLE I.—*Corn varieties in the order of their earliness in reaching maturity.*

Class 1.	Class 2.	Class 3.
Very early varieties: Gehu Flint. Northwestern Dent. Minnesota 23. Brown County Yellow. Ardmore Yellow. Mitchell Blue Flour.	Early varieties: Martens White Dent. U. S. Selection 133. Minnesota 13. Cassia County Flint. White Australian. Swadley. Dakota Red Squaw. Ninety-Day Disco. Amber Flint. Mitchell Calico. Golden Glow. Colorado Early Select. Wisconsin 7.	Comparatively late varieties: North Platte Silver Mine. North Platte Calico. U. S. Selection 160.

RESULTS OF TESTS OF VARIETIES.

Tests of corn varieties have been conducted at several stations in the north-central Great Plains area. Yields secured for each station and year when a successful crop has been produced are shown in Tables II to VII. These yields do not indicate what may usually be expected in any locality in an average or normal season. They more nearly represent what may be expected in favorable seasons under good farming practice.

Careful attention has been given to securing uniform conditions for all varieties in each test, but no unusual or intensive methods of cultivation or manuring have been employed. At all places where the crop has depended upon the natural rainfall for moisture, total failures or very low yields have resulted in some years. The results indicate the behavior of different varieties under the same conditions.

Since small differences are of little importance in judging the value of different varieties, the varieties are divided into three classes according to yield for each year and the result is shown in the last three columns of the summary tables. Class 1 is made up of varieties yielding above the average; class 2 of varieties of about average yield, and class 3 of varieties yielding less than the average. In calculating yields, 70 pounds of dry ears are used for 1 bushel.

TESTS AT HUNTLEY.

The tests at Huntley, Mont., have been made under irrigation. Three years' results are available. In 1912 the test contained 6 varieties; in 1913, 7 varieties; and in 1914, 11 varieties. Each variety unit was composed of two rows; in 1912 and 1913 these rows were 132 feet long and $3\frac{1}{2}$ feet apart, making an area of about one-forty-seventh acre per plat; in 1914 the rows were 170 feet long and $3\frac{3}{8}$ feet apart, making the plats one thirty-fifth acre in area.

In 1913 and 1914 the variety plats were alternated with check plats planted to a common variety, and the series was repeated three times. In 1913 the check plats were planted to Minnesota 13, and in 1914 to Northwestern Dent. The seed was drilled in the rows, and the plants later thinned to one about every 18 inches. The yield in pounds of ears for each variety and check plat and the total yield of each variety are shown in Table II. Check plats are totaled in groups of threes, to correspond with the total yields of varieties. In 1913 there were large differences in yields of replicate plats of the same variety and between the yields of check plats. The test for that year has little value except as the results corroborate those of other years in indicating good varieties. In 1914 the differences were smaller between replicate plat yields and the results were more reliable.

The yields in bushels per acre, the increase of the variety over adjacent checks, and the rank and class of each variety according to yield are shown in the summary of Table II. For 1912 the varieties are ranked according to actual yield. For 1913 and 1914 the varieties are ranked according to the amount by which the average yield of the three plats of each variety exceeds the average yield of the six check plats adjacent to them. The varieties which have yielded relatively high in all tests at Huntley are Northwestern Dent and U. S. Selection 133.

TABLE II.—Yield of corn varieties grown at Huntley, Mont., by plats, for the years stated.

Year and variety.	Plat No.	Yield of ears.	Plat No.	Yield of ears.	Plat No.	Yield of ears.	Total yield.
		<i>Pounds.</i>		<i>Pounds.</i>		<i>Pounds.</i>	<i>Pounds.</i>
Season of 1913:							
Minnesota 13.....	1	45	13	14	25	46	105
Northwestern Dent.....	2	48	14	27	26	42	117
Minnesota 13.....	3	48	15	31	27	43	126
Minnesota 23.....	4	35	16	27	28	42	104
Minnesota 13.....	5	47	17	33	29	39	119
U. S. Selection 133.....	6	43	18	28	30	49	120
Minnesota 13.....	7	34	19	26	31	65	125
Brown County Yellow.....	8	30.5	20	21.5	32	57	109
Minnesota 13.....	9	31	21	26	33	77	134
Ardmore.....	10	23	22	28	34	68	119
Minnesota 13.....	11	15	23	27	35	70	112
Amber Flint.....	12	10	24	25	36	50	85
Minnesota 13.....	13	14	25	46	37	81	141
Season of 1914:							
Northwestern Dent.....	1	75	21	105	41	106	286
Minnesota 13.....	2	72	22	88	42	80	240
Northwestern Dent.....	3	79	23	111	43	94	284
U. S. Selection 133.....	4	72	24	104	44	113	289
Northwestern Dent.....	5	111	25	117	45	105	333
Minnesota 23.....	6	68	26	74	46	71	213
Northwestern Dent.....	7	100	27	108	47	96	304
Brown County Yellow.....	8	95	28	105	48	79	279
Northwestern Dent.....	9	97	29	115	49	90	302
Martens White Dent.....	10	109	30	126	50	108	343
Northwestern Dent.....	11	99	31	96	51	92	287
Gehu Flint.....	12	70	32	83	52	69	222
Northwestern Dent.....	13	97	33	116	53	65	279
Cassia County Flint.....	14	112	34	130	54	103	345
Northwestern Dent.....	15	101	35	103	55	94	298
Triumph Flint.....	16	102	36	123	56	119	344
Northwestern Dent.....	17	106	37	93	57	94	293
Fort Peck Squaw.....	18	48	38	75	58	46	169
Northwestern Dent.....	19	108	39	106	59	81	295
Longfellow Flint.....	20	83	40	90	60	91	264
Northwestern Dent.....	21	105	41	106	61	78	290

SUMMARY SHOWING THE RELATIVE RANK AND CLASS OF EACH VARIETY FOR THE YEARS 1912, 1913, AND 1914.

Variety.	Yield per acre (bushels).			Increase over average of adjacent checks (bushels).		Rank.			Class.		
	1912 (1 plat).	1913 (3 plats).	1914 (3 plats).	1913 (3 plats).	1914 (3 plats).	1912 (1 plat).	1913 (3 plats).	1914 (3 plats).	1912 (1 plat).	1913 (3 plats).	1914 (3 plats).
Northwestern Dent....	58.5	25.0	49.0	0	0	4	2	4	1	1	1
Brown County Yellow....	51.5	24.5	46.5	-3.7	-4.0	6	5	6	2	2	2
Minnesota 23.....	59.0	27.4	41.0	0	-8.2	3	1	8	1	1	3
Minnesota 13.....	52.0	24.0	35.5	-2.5	-17.5	5	3	10	2	2	3
U. S. Selection 133.....	63.0	26.0	51.5	-.7	-1.7	1	3	5	1	1	1
Wisconsin 7.....	62.0					2			1		
Ardmore Yellow.....		25.5		-.7			3			1	
Amber Flint.....		18.0		-5.5			6			3	
Martens White Dent.....			57.0		9.5			3			1
Gehu Flint.....			37.0		-10.2			9			3
Triumph Flint.....			57.5		10.0			2			1
Fort Peck Squaw.....			28.0		-21.0			11			3
Longfellow Flint.....			44.0		-4.7			7			3
Cassia County Flint.....			57.5		12.5			1			1

TESTS AT NEWELL.

Results covering three years are available from the station at Newell, S. Dak. In 1912 the test was on dry land. The variety units were single rows 132 feet long, with the rows $3\frac{1}{2}$ feet apart. The variety rows were alternated with check rows planted with

Northwestern Dent seed and the series was repeated five times, making a total area for each variety of about one-nineteenth of an acre. The yield in pounds of ears for each row and the total yield of each variety are shown in Table III. In 1913 and 1914 the tests were made on both irrigated and dry land. The dry-land tests were so badly injured by drought in both years that yield records were not secured. The irrigated plantings were made in 2-row units and the series repeated twice in 1913 and three times in 1914. The yield in pounds of ears for each plat and the total yield of each variety are also shown in Table III. The check-plat yields are totaled by twos or threes, to correspond with the total yields of varieties.

The yields in bushels per acre and the rank and class of each variety for the three years are shown in the summary of Table III. The rankings are given according to the average yields of the plats of each variety.

U. S. Selection 133 has produced relatively well in all three years. Martens White Dent has outyielded all other varieties by a considerable amount in the two years in which it was grown.

TABLE III.—Yield of corn varieties grown at Newell, S. Dak., on dry land and under irrigation, by plats, for the years stated.

Variety.	Row No.	Yield of ears.	Row No.	Yield of ears.	Row No.	Yield of ears.	Row No.	Yield of ears.	Row No.	Yield of ears.	Total yield.
On dry land, in 1912:		<i>Lbs.</i>		<i>Lbs.</i>		<i>Lbs.</i>		<i>Lbs.</i>		<i>Lbs.</i>	<i>Lbs.</i>
Ardmore Yellow.....	1	15.0	33	16.8	65	17.0	97	19.4	129	17.4	85.6
Minnesota 13.....	2	14.5	34	13.5	66	14.5	98	18.1	130	15.2	75.8
Ardmore Yellow.....	3	14.2	35	17.8	67	20.8	99	21.0	131	17.4	91.2
Minnesota 23.....	4	12.8	36	13.6	68	15.8	100	16.3	132	16.9	75.4
Ardmore Yellow.....	5	16.2	37	19.4	69	19.0	101	22.2	133	18.6	95.4
U. S. Selection 133.....	6	15.4	38	15.4	70	16.8	102	20.2	134	24.3	92.1
Ardmore Yellow.....	7	15.4	39	17.8	71	19.2	103	18.8	135	16.8	88.0
Brown County Yellow.....	8	14.6	40	14.9	72	14.9	104	17.0	136	18.6	80.0
Ardmore Yellow.....	9	17.0	41	18.4	73	17.8	105	19.2	137	21.2	93.6
Red Squaw.....	10	4.6	42	6.4	74	9.7	106	10.6	138	15.1	46.4
Ardmore Yellow.....	11	14.1	43	16.2	75	16.2	107	19.6	139	17.0	83.1
Wisconsin 7.....	12	8.1	44	9.1	76	10.8	108	14.5	140	15.9	58.2
Ardmore Yellow.....	13	15.2	45	15.8	77	19.0	109	19.0	141	20.6	89.6
Golden Glow.....	14	11.2	46	14.9	78	14.5	110	17.6	142	20.1	78.3
Ardmore Yellow.....	15	14.0	47	18.6	79	19.8	111	18.4	143	21.8	92.6
U. S. Selection 133 × U. S. Selection 160.....	16	9.6	48	10.2	80	11.8	112	14.7	144	13.8	60.1
Ardmore Yellow.....	17	15.4	49	12.5	81	18.0	113	15.0	145	16.6	77.5
Brown County × U. S. Selection 160.....	20	11.0	52	12.3	84	13.1	116	13.6	148	20.6	70.6
Ardmore Yellow.....	21	14.0	53	14.8	85	17.4	117	17.2	149	21.8	85.2
U. S. Selection 160.....	22	2.6	54	3.7	86	3.0	118	4.7	150	8.9	22.9
Ardmore Yellow.....	23	14.6	55	14.8	87	17.0	119	16.2	151	19.8	82.4
White Australian.....	24	14.0	56	19.3	88	19.3	120	21.0	152	23.5	97.1
Ardmore Yellow.....	25	15.0	57	13.2	89	17.6	121	17.6	153	16.2	79.6
White Australian × U. S. Selection 160.....	26	6.4	58	7.5	90	11.2	122	8.7	154	14.6	48.4
Ardmore Yellow.....	27	15.8	59	17.8	91	16.8	123	16.8	155	17.4	84.6
Northwestern Dent.....	28	14.8	60	15.8	92	16.6	124	14.8	156	17.8	79.7
Ardmore Yellow.....	29	15.4	61	17.0	93	19.0	125	17.8	157	16.6	85.8
Payne White Dent.....	30	15.1	62	17.7	94	21.6	126	20.4	158	23.6	98.4
Ardmore Yellow.....	31	17.3	63	16.2	95	19.4	127	15.6	159	12.9	81.4

TABLE III.—*Yield of corn varieties grown at Newell, S. Dak., on dry land and under irrigation, by plats, for the years stated—Continued.*

UNDER IRRIGATION IN 1913.

Variety.	Plat No.	Yield of ears.	Plat No.	Yield of ears.	Total yield.
		<i>Pounds.</i>		<i>Pounds.</i>	<i>Pounds.</i>
Ardmore Yellow.....	1	76.5	10	84.0	160.5
Northwestern Dent.....	2	87.5	11	85.7	173.2
Brown County Yellow.....	3	82.7	12	84.5	167.2
U. S. Selection 133.....	4	85.0	13	102.5	187.5
Ninety-Day Disco.....	5	79.5	14	95.2	174.5
Amber Flint.....	6	64.5	15	74.2	138.7
Martens White Dent.....	7	104.0	16	93.2	197.2
Minnesota 23.....	8	57.7	17	60.7	118.4
Payne White Dent.....	9	101.5	18	79.0	180.5

UNDER IRRIGATION IN 1914.

Variety.	Plat No.	Yield of ears.	Plat No.	Yield of ears.	Plat No.	Yield of ears.	Total yield.
		<i>Pounds.</i>		<i>Pounds.</i>		<i>Pounds.</i>	<i>Pounds.</i>
Northwestern Dent.....	1	60.0	9	66.5	17	50.0	176.5
Brown County Yellow.....	2	64.5	10	74.0	18	66.0	198.0
Ardmore Yellow.....	3	65.0	11	62.0	19	73.0	200.0
U. S. Selection 133.....	4	80.0	12	65.0	20	82.5	227.5
Ninety-Day Disco.....	5	74.0	13	62.5	21	73.0	209.5
Lyman White Cap.....	6	62.0	14	69.0	22	82.0	223.0
Martens White Dent.....	7	78.0	15	82.5	23	90.0	251.0
Payne White Dent.....	8	62.0	16	68.5	24	75.5	206.0

SUMMARY SHOWING THE RELATIVE RANK AND CLASS OF EACH VARIETY FOR THE YEARS 1912, 1913, AND 1914.

Variety.	Yield per acre (bushels).			Rank.			Class.		
	1912 (5 plats).	1913 (2 plats).	1914 (3 plats).	1912 (5 plats).	1913 (2 plats).	1914 (3 plats).	1912 (5 plats).	1913 (2 plats).	1914 (3 plats).
Ardmore Yellow.....	23.0	49.0	37.5	4	6	5	1	2	2
Northwestern Dent.....	21.5	56.0	30.0	5	2	7	1	1	3
U. S. Selection 133.....	25.0	56.0	41.0	3	2	3	1	1	1
Brown County Yellow.....	21.5	51.0	38.0	5	5	4	1	2	2
Payne White Dent.....	26.5	55.5	37.0	1	3	6	1	1	3
Minnesota 23.....	20.5	38.5	.....	7	8	.....	2	3	.....
Minnesota 13.....	20.0	.....	.....	8	.....	.....	2	.....	.....
Wisconsin 7.....	15.5	.....	.....	11	.....	.....	3	.....	.....
Golden Glow.....	21.0	.....	.....	6	.....	.....	2	.....	.....
White Australian.....	26.0	.....	.....	2	.....	.....	1	.....	.....
Red Squaw.....	12.5	.....	.....	14	.....	.....	3	.....	.....
U. S. Selection 160.....	6.0	.....	.....	15	.....	.....	3	.....	.....
Ninety-Day Disco.....	.....	54.5	37.5	.....	4	5	.....	1	2
Amber Flint.....	.....	45.5	.....	.....	7	.....	.....	3	.....
Martens White Dent.....	.....	60.5	48.0	.....	1	1	.....	1	1
Lyman White Cap.....	.....	.....	42.0	.....	.....	2	.....	.....	1
U. S. Selection 133 × U. S. Selection 160.....	16.0	.....	.....	10	.....	.....	3	.....	.....
Brown County Yellow × U. S. Selection 160.....	19.0	.....	.....	9	.....	.....	3	.....	.....
White Australian × U. S. Selection 160.....	13.0	.....	.....	13	.....	.....	3	.....	.....
Curren × U. S. Selection 160.....	15.0	.....	.....	12	.....	.....	3	.....	.....

TESTS AT MITCHELL.

Results covering three years are available from the station at Mitchell, Nebr. The tests have been made each year on irrigated and on dry land. In 1914 the crop on dry land was injured badly by drought and no yield records were made.

The units were in all years 2-row plats, 132 feet long and 7 feet wide. In 1912 no check plats were grown. In 1913 and 1914 the variety plats were alternated with check plats in which a common

variety was grown. The series were duplicated in all years, making a total area for each variety of about one twenty-fifth of an acre. The yield in pounds of ears for each plat and the total yield of each variety are shown in Table IV. In that portion of the table relating to 1913 and 1914 the yields of check plats are totaled by twos, to correspond with the total yields of varieties. Yields per acre, the ranking of varieties, and the variety classes are given in the summary. The rankings in 1912 are according to average yields of dry ears for the plats of each variety. The rankings for 1913 and 1914 are according to the amount the average yield of the two plats of each variety exceeds the average of the four check plats adjacent to them.

TABLE IV.—*Yield of corn varieties grown at Mitchell, Nebr., on dry land and under irrigation, by plats, for the years stated.*

Variety.	On dry land.				Under irrigation.				Total yield.	
	Plat No.	Yield of ears.	Plat No.	Yield of ears.	Plat No.	Yield of ears.	Plat No.	Yield of ears.	Dry land.	Irrigated.
Season of 1912:		<i>Pounds.</i>		<i>Pounds.</i>		<i>Pounds.</i>		<i>Pounds.</i>	<i>Pounds.</i>	<i>Pounds.</i>
Local white.....	1	69.5	20	75.4	1	69.2	24	74.0	144	143.2
U. S. Selection 160.....	2	44.5	21	47.0	2	45.7	25	.....	91	¹ 45.7
White Australian.....	4	105.0	23	87.0	4	77.5	27	74.5	192	152.0
Wisconsin 7.....	5	67.5	24	71.5	5	55.0	28	63.0	139	118.0
Martens White Dent.....	6	97.3	25	70.0	6	63.0	29	63.0	167.3	126.0
Golden Glow.....	8	70.0	27	73.0	8	57.4	31	72.5	143.0	129.9
Golden Ideal.....	9	58.7	28	66.2	9	55.4	32	58.7	124.9	114.1
Brown County Yellow.....	10	60.9	29	69.4	10	60.6	33	62.0	130.3	122.6
Minnesota 13.....	12	66.6	31	60.5	12	77.0	35	73.5	127.1	150.5
Minnesota 23.....	13	60.3	32	56.6	13	70.5	36	71.2	116.9	141.7
U. S. Selection 133.....	14	76.5	33	64.8	14	62.7	37	66.5	141.3	129.2
Red Squaw.....	15	85.2	34	64.5	15	88.2	38	62.5	149.7	144.7
North Platte Calico.....	16	47.4	35	45.8	16	52.2	39	.....	93.2	¹ 52.2
Mitchell Calico.....	18	44.8	37	34.1	18	67.0	41	62.5	135.7	129.5
Salzer Fodder.....	19	46.5	38	.....	19	67.0	42	.....	¹ 46.5	¹ 67.0
Australian Flint X U. S. Selection 160.....				.....	22	80.2	45	72.3	.....	152.5
Brown County Yellow X U. S. Selection 160.....				.....	23	67.2	46	67.5	.....	134.7
Colorado Early Yellow.....			39	62.7						
Do.....			40	61.5					124.2	
Season of 1913:										
Mitchell Calico.....			26	40.5			26	61.8		
Ardmore.....	1	32.1	27	38.6	1	49.3	27	54.8	70.7	104.1
Mitchell Calico.....	2	30.5	28	40.5	2	56.4	28	61.4	71.0	117.8
Ardmore X U. S. Selection 133.....	3	35.5	29	41.6	3	57.7	29	59.4	77.1	117.1
Mitchell Calico.....	4	33.0	30	37.2	4	58.1	30	61.0	70.2	119.1
U. S. Selection 133.....	5	40.0	31	43.2	5	62.2	31	68.0	83.2	130.2
Mitchell Calico.....	6	37.2	32	37.6	6	57.2	32	61.8	74.8	119.0
Brown County Yellow X U. S. Selection 133.....	7	39.1	33	32.8	7	52.8	33	59.4	71.9	112.3
Mitchell Calico.....	8	37.2	34	35.5	8	58.0	34	63.0	72.7	121.0
Brown County Yellow Dent.....	9	33.1	35	32.2	9	48.1	35	49.8	65.3	97.9
Mitchell Calico.....	10	35.1	36	39.2	10	51.4	36	57.2	74.3	108.6
Colorado Early Select.....	11	28.8	37	28.4	11	55.0	37	63.9	57.2	118.9
Mitchell Calico.....	12	33.5	38	36.3	12	53.5	38	59.0	69.8	112.5
Haldeen.....	13	38.1	39	29.8	13	43.8	39	55.2	67.9	99.0
Mitchell Calico.....	14	38.4	40	33.5	14	53.9	40	60.2	71.9	114.1
Martens White Dent.....	17	42.4	43	39.0	17	51.1	43	61.6	81.4	115.7
Mitchell Calico.....	18	38.4	44	32.6	18	58.5	44	60.2	71.0	118.7
Ninety-Day Disco.....	19	45.6	45	24.2	19	53.7	45	67.0	69.8	120.7
Mitchell Calico.....	20	43.8	46	31.3	20	60.7	46	64.0	75.1	124.7
Minnesota 23.....	21	32.6	47	21.6	21	35.5	47	56.3	54.2	91.7
Mitchell Calico.....	22	38.0	48	20.5	22	58.9	48	63.9	58.5	122.8
Amber Flint.....	23	20.2	49	7.8	23	32.6	49	68.0	28.1	100.6
Mitchell Calico.....	24	41.4	50	5.8	24	58.9	50	64.0	47.2	122.9
Mitchell Blue Flour.....	25	33.5	51	17.7	25	70.4	51	75.0	51.2	145.4
Mitchell Calico.....	26	40.5	52	14.2	26	61.8	52	.....	54.7	.....

¹ Single plat.

TABLE IV.—*Yield of corn varieties grown at Mitchell, Nebr., on dry land and under irrigation, by plats, for the years stated—Continued.*

Variety.	Plat No.	Yield of ears.	Plat No.	Yield of ears.	Total yield.
Season of 1914, under irrigation:		<i>Pounds.</i>		<i>Pounds.</i>	<i>Pounds.</i>
Mitchell Calico.....			22	108.5	
Martens White Dent.....	1	103.5	23	102.0	205.5
Mitchell Calico.....	2	113.0	24	98.0	211.0
Martens White Dent × Calico.....	3	103.0	25	107.0	210.0
Mitchell Calico.....	4	110.0	26	102.0	212.0
Local White.....	5	117.5	27	98.0	215.5
Mitchell Calico.....	6	114.5	28	107.0	221.5
Ninety-Day Disco × Calico.....	7	123.0	29	120.0	243.0
Mitchell Calico.....	8	103.0	30	106.0	209.0
Golden Glow.....	9	111.0	31	107.0	218.0
Mitchell Calico.....	10	107.0	32	109.5	216.0
U. S. Selection 133.....	11	115.0	33	111.0	226.0
Mitchell Calico.....	12	109.0	34	113.0	222.0
Brown County Yellow.....	13	94.5	35	92.5	187.0
Mitchell Calico.....	14	104.5	36	111.0	215.5
Northwestern Dent.....	15	90.5	37	92.5	183.0
Mitchell Calico.....	16	98.0	38	100.0	198.0
White Australian.....	17	117.0	39	131.0	248.0
Mitchell Calico.....	18	98.5	40	103.0	201.5
Blue Flour.....	19	42.0	41	76.0	118.0
Mitchell Calico.....	20	105.5	42	110.0	215.5
Ardmore Yellow.....	21	87.5	43	97.0	184.5
Mitchell Calico.....	22	108.5	44	103.0	

SUMMARY SHOWING THE RELATIVE RANK AND CLASS OF EACH VARIETY FOR THE YEARS 1912, 1913, AND 1914.

Variety (2 plats of each variety each year).	Yield per acre (bushels).					Rank.					Class.				
	Dry land.		Irrigated.			Dry land.		Irrigated.			Dry land.		Irrigated.		
	1912	1913	1912	1913	1914	1912	1913	1912	1913	1914	1912	1913	1912	1913	1914
Mitchell Calico.....	45.0	23.0	43.0	35.0	73	8	5	9	4	5	1	2	2	2	2
Local White.....	48.0		47.5		74	4		5		6	1		1		2
Martens White Dent.....	56.0	27.5	42.0	34.0	70	2	1	10	6	8	1	1	2	2	2
U. S. Selection 133.....	47.0	28.0	43.0	39.0	78	6	2	9	2	3	1	1	2	1	1
Brown County Yellow.....	43.5	22.0	41.0	29.0	64	9	10	11	12		2	3	2	3	3
White Australian.....	64.0	50.5	50.5		85	1		2		1	1		1		1
Minnesota 13.....	42.5		50.0			10		3			2		1		
Minnesota 23.....	39.0	18.5	47.0	27.0		12	11	6	13		3	3	1	3	
Wisconsin 7.....	46.5		39.0			7		12			1		2		
Golden Glow.....	47.5		43.0		75	5		9		4	1		2		2
Golden Ideal.....	41.5		38.0			11		13			2		2		
Red Squaw.....	50.0		48.0			3		4			1		1		
North Platte Calico.....	31.0		35.0			13		14			3		3		
Salzer Fodder.....	31.0		44.5			13		8			3		2		
U. S. Selection 160.....	30.5		30.5			14		15			3		3		
Ardmore Yellow.....		24.0		31.0	63		6		9	10		2		2	3
Colorado Early Select.....		19.5		36.0			12		3			3		1	
Haldeen.....		23.0		29.5			9		10			2		2	
Ninety-Day Disco.....		23.5		36.0			8		5			2		2	
Amber Flint.....		9.5		30.0			13		11			3		3	
Mitchell Blue Flour.....		17.5		43.0			4		1			2		1	
Northwestern Dent.....					63					9					3
White Australian × U. S. Selection 160.....			51.0					1					1		
Brown County Yellow × U. S. Selection 160.....			45.0					7					2		
Ardmore × U. S. Selection 133.....		26.0		35.0			3		8			1		2	
Brown County × U. S. Selection 133.....		25.0		34.0			7		7			1		2	
Martens White Dent × Calico.....					72					7					2
Ninety-Day Disco × Calico.....					83					2					1

U. S. Selection 133, Martens White Dent, and Mitchell Calico have all produced relatively well. The yield differences between these

varieties are not sufficiently large to indicate the superiority of any one of them. White Australian has occupied a very high rank in the years in which it has been grown. It should be given further trial as a corn for hogging off.

TESTS AT NORTH PLATTE.

The results of only one year are available from the station at North Platte, Nebr. The tests were made on dry land. Plantings were made in 1912, 1913, and 1914. In 1913 and 1914 the drought injury was so severe that yield records were not made. The variety units were made up of plats 175 feet long and 7 feet wide, making an area of about one thirty-fifth of an acre, and each plat contained two rows. The variety plats were alternated with check plats, all planted to the same variety. The series was grown in duplicate.

The yields in pounds of ears of each plat and the total pounds of ears produced by the two plats of each variety are shown in Table V. In the total column, the yields of the check plats are combined by twos in the same order as the plats of the different varieties.

Actual and corrected yields per acre and the rank and class of each variety are shown in the summary. The corrected yields are secured by decreasing or increasing the actual average yield of the two plats of each variety by the amount the average yield of the four adjacent check plats exceeds or falls below the average yield of all check plats. The rankings are according to corrected yields.

TABLE V.—Yield of corn varieties grown at North Platte, Nebr., on dry land, by plats, in 1912.

Variety.	Plat No.	Yield of ears.	Plat No.	Yield of ears.	Total.
		<i>Pounds.</i>		<i>Pounds.</i>	<i>Pounds.</i>
North Platte Calico.....	1	111.4	28	89.9	301.3
Clarage.....	2	96.7	29	89.1	185.8
North Platte Calico.....	3	97.9	30	99.4	197.3
Golden Ideal.....	4	91.9	31	88.2	174.1
North Platte Calico.....	5	103.9	32	85.2	189.1
Reid Yellow Dent.....	6	73.8	33	45.0	118.8
North Platte Calico.....	7	107.0	34	73.8	180.8
Local Yellow.....	8	80.4	35	58.0	138.4
North Platte Calico.....	9	95.7	36	66.3	162.0
University 3.....	10	81.2	37	69.3	150.5
North Platte Calico.....	11	92.3	38	69.3	161.6
Chase County Blue Flour.....	12	96.9	39	71.0	167.9
North Platte Calico.....	13	78.4	40	66.4	144.8
North Platte Silver Mine.....	14	83.3	41	75.9	159.2
North Platte Calico.....	15	87.4	42	78.7	166.1
Martens White Dent.....	16	86.0	43	88.5	174.5
North Platte Calico.....	17	85.8	44	81.4	167.2
White Australian.....	18	68.6	45	79.6	148.2
North Platte Calico.....	19	88.8	46	79.8	167.6
Minnesota 13.....	20	82.6	47	84.7	167.3
North Platte Calico.....	21	101.7	48	87.3	188.7
U. S. Selection 133.....	22	83.8	49	83.8	167.6
North Platte Calico.....	23	104.6	50	79.8	184.4
Wisconsin 7.....	24	79.0	51	73.1	152.1
North Platte Calico.....	25	88.1	52	76.8	164.9
U. S. Selection 160.....	26	59.4	53	56.9	116.3
North Platte Calico.....	27	78.3	54	82.1	160.4

TABLE V.—*Yield of corn varieties grown at North Platte, Nebr., on dry land, by plats, in 1912—Continued.*

SUMMARY SHOWING THE RELATIVE RANK AND CLASS OF EACH VARIETY.

Variety.	Yield per acre (bushels).		Rank (2 plats).	Class (2 plats).	Variety.	Yield per acre (bushels).		Rank (2 plats).	Class (2 plats).
	Actual (2 plats).	Cor-rected (2 plats).				Actual (2 plats).	Cor-rected (2 plats).		
Clarage.....	47.0	40.5	6	2	Martens White Dent	44.5	45.5	2	1
Golden Ideal.....	44.5	39.5	7	2	White Australian..	38.0	39.5	7	2
Reid Yellow Dent..	30.0	27.5	12	3	Minnesota 13.....	42.5	41.5	5	2
Local Yellow.....	35.0	36.0	10	3	U. S. Selection 133..	42.5	39.5	8	2
University 3.....	38.5	41.5	5	2	Wisconsin 7.....	38.5	38.5	9	3
Chase County Blue					U. S. Selection 160..	39.5	32.5	11	3
Flour.....	42.5	48.0	1	1	Calico (average of 28 checks).....	44.2	44.2	4	1
North Platte Silver Mine.....	40.5	45.0	3	1					

TESTS AT AKRON.

The results of only one year are available from the station at Akron, Colo. The crop was grown without irrigation. Plantings were made in 1912, 1913, and 1914. In 1913 the crop was so nearly a total failure on account of injury from drought that no yield records were secured. In 1914 a partial crop was developed, but the stands secured were so irregular that the results are not considered worthy of presentation.

The variety units in 1912 were single-row plats 175 feet long and $3\frac{1}{2}$ feet wide, making an area of about one seventy-first of an acre. Plantings were made in hills $3\frac{1}{2}$ feet apart at three different rates, one, two, and three per hill. The two-per-hill section was planted in duplicate. The variety rows were alternated with check rows all planted with Swadley corn.

The yields in pounds of ears for each plat are shown in Table VI. The yields in bushels per acre and the rank and class of each variety are shown in the summary.

The highest yields were secured from the thickest plantings. The lowest yield was secured from the one-per-hill rate and the highest yield from the three-per-hill rate. The yield at the two-per-hill rate was intermediate between the other two rates, but nearer the yield from the three-per-hill rate. It should be borne in mind that this season was more favorable than normal, and the results obtained should not be interpreted as indicating that stands of three stalks per hill will produce best in average years. Rates thicker than two stalks per hill with the hills $3\frac{1}{2}$ feet apart each way are not recommended for dry-land plantings. There is less difference between the yields from different rates of varieties which sucker profusely than between rates of nonsuckering varieties. The White Australian and Red Squaw produce a large number of suckers, while the dent varieties produce but few.

TABLE VI.—Yield of corn varieties grown at Akron, Colo., by plats, at three different rates of planting per hill, for the year 1912.

Variety.	Plat No.	Yield of ears.	Plat No.	Yield of ears.	Plat No.	Yield of ears.	Plat No.	Yield of ears.
Number of plants per hill.....		2		1		3		2
		Pounds.		Pounds.		Pounds.		Pounds.
Swadley.....	1	39.2					54	34.4
White Australian (N. Mex.).....	2	40.2					55	34.3
Swadley.....	3	30.6					56	34.4
White Australian (Colo.).....	4	47.2	28	40.4	41	45.3	57	44.6
Swadley.....	5	32.4	29	43.0	42	48.0	58	32.6
Cassia County Flint.....	6	26.9					59	36.2
Swadley.....	7	36.4					60	31.8
Kiabab Flint.....	8	42.5					61	42.2
Swadley.....	9	33.6					62	33.4
Gehu Flint.....	10	30.9					63	33.0
Swadley.....	11	33.0					64	33.6
Red Squaw.....	12	39.0	30	43.0	43	43.4	65	43.0
Swadley.....	13	34.8	31	44.0	44	48.0	66	30.0
Brown County Yellow.....	14	32.0	32	26.1	45	35.8	67	28.3
Swadley.....	15	34.0	33	42.5	46	31.5	68	31.0
Minnesota 23.....	16	30.8	34	23.4	47	35.0	69	30.0
Swadley.....	17	38.3	35	38.0	48	50.7	70	33.6
Minnesota 13.....	18	42.5	36	34.7	49	40.5	71	34.9
Swadley.....	19	41.5	37	36.2	50	45.0	72	32.6
U. S. Selection 133.....	20	43.5	38	29.7	51	43.8	73	35.0
Swadley.....	21	33.9	39	41.0	52	42.5	74	35.3
Golden Glow.....	22	45.5	40	30.8	53	47.6	75	39.0
Swadley.....	23	38.7					76	33.0
U. S. Selection 160.....	24	27.0					77	24.4
Swadley.....	25	34.9					78	33.0
North Platte Calico.....	26	40.2					79	34.5
Swadley.....	27	35.5					80	27.4

SUMMARY SHOWING THE RELATIVE RANK AND CLASS OF EACH VARIETY.

Variety.	Yield per acre (bushels).			Rank.	Class.	Variety.	Yield per acre (bushels).			Rank.	Class.
Number of plats averaged.....	1	2	1	2	2	Number of plats averaged.....	1	2	1	2	2
Number of plants per hill.....	1	2	3	2	2	Number of plants per hill.....	1	2	3	2	2
White Australian (N. Mex.).....		38.0		7	2	Minnesota 23.....	24.0	31.0	35.5	11	3
White Australian (Colo.).....	43.0	46.5	46.0	1	1	Minnesota 13.....	35.5	39.5	41.0	6	1
Cassia County Flint.....		32.0		10	3	U. S. Selection 133.....	30.0	40.0	44.5	5	1
Kiabab Flint.....		43.0		2	1	Golden Glow.....	31.5	43.0	48.5	3	1
Gehu Flint.....		32.5		9	3	U. S. Selection 160.....		26.0		13	3
Red Squaw.....	44.0	41.5	44.0	4	1	North Platte Calico.....		38.0		7	2
Brown County Yellow.....	26.5	30.5	36.5	12	3	Swadley (average of 14 checks)....		34.5		8	2

SUMMARY OF TESTS.

Small differences are of importance only when it is certain that such differences are due to potential varietal qualities and not chance fluctuations. On account of seasonal fluctuations and the difficulty of eliminating experimental error, it is not possible from the results of one or a few tests to determine to what causes small differences are due. In preliminary and short-time trials only differences of considerable amount should be taken into account. These indicate in a general way the comparative adaptability of varieties to the conditions of the test. In districts such as the Great Plains area, where

but little attention has been given to seed selection, most of the so-called varieties vary widely within themselves, and established types are few. In varietal tests containing these varying types any small differences which may appear are obviously of little importance.

In varietal tests in which seed is assembled from different localities those varieties usually give the best results which have been grown for some time under conditions similar to those where the test is made. Such varieties are said to be acclimated or to have become adjusted to the conditions where grown. Much emphasis has been laid on the importance of this factor. The usual recommendation is that if locally grown seed can be secured it is unwise to introduce seed from a distance for general planting, even if the introduced seed has proved to be of superior value where grown. While this recommendation seems to be justified by the large number of cases in which the locally grown seed has proved superior, it has in some cases been overemphasized by comparing averages rather than the performances of individual varieties. Since wide differences usually occur among introduced varieties and the average is lowered by those strikingly unadapted, this practice is obviously unfair to the best varieties.

While natural selection is said to operate to adjust varieties to the conditions where grown, there is very little exact knowledge regarding the operation and effect of these so-called acclimatization and adaptation factors. Some varieties do well in certain localities or under certain conditions, but seem unable to respond to changed conditions. Other varieties are more adaptable and perform well under widely different conditions. To assume that a variety is best for a locality because it has had an opportunity to become acclimated may be as false a conclusion as to assume that a variety will do well in one locality because it has done so in some other locality. There seems at present to be no rule by which the performance or relative adaptation of different varieties to different conditions can be determined except by bringing them together in comparative tests.

In the summaries of tables previously given, the varieties are divided into three classes, according to whether the comparative yields are good, average, or poor. The standing of all varieties according to this classification, from all the tests, is given in Table VII.

Certain varieties have given good results in nearly all tests. Their yields have varied widely as conditions were favorable or unfavorable, but their production as compared with that of other varieties has remained uniformly good. The most outstanding of these have been White Australian, Martens White Dent, and U. S. Selection 133. Two of these have been grown under Plains conditions for a num-

ber of years, while the third, U. S. Selection 133, has been developed in Wisconsin and the seed introduced from there each year.

TABLE VII.—*Yield and class standing of each variety of corn for each test.*

Variety.	Huntley, Mont.			Newell, S. Dak.			Mitchell, Nebr.					North Platte, Nebr.	Akron, Colo.
	Irrigated.			Dry land.	Irrigated.		Dry land.		Irrigated.			Dry land.	
	1912	1913	1914	1912	1913	1914	1912	1913	1912	1913	1914	1912	1912
U. S. Selection 133.....	1	1	1	1	1	1	1	1	2	1	1	2	1
Martens White Dent.....			1		1	1	1	1	2	2	2	1	
Brown County Yellow.....	2	2	2	1	2	2	2	2	2	3	3		3
Minnesota 13.....	1	1	3	2			2		1				1
Minnesota 23.....	2	2	3	2	3		3	3	1	3			3
White Australian.....				1			1		1			2	1
Wisconsin 7.....	1	2		3			2		3			3	
Golden Glow.....			1	1			1		2				1
Ardmore.....		1		1	2	2	1		2	3			
Northwestern Dent.....	1	2	1	2	1	3					3		
Red Squaw.....				3			1		1				1
U. S. Selection 160.....				3			3		3			3	3
Mitchell Calico.....							2	1	2	2	2		
North Platte Calico.....							3		3			1	2
Mitchell Local White.....							1		1		2		
North Platte Silver Mine.....												1	
Payne White Dent.....				1	1	2							
Haldeen.....								1		3			
Colorado Early Select.....								2		1			
Ninety-Day Disco.....					1	3		1		1			
Amber Flint.....		3			3			3		3			
Mitchell Blue Flour.....								3		1			
Lyman White Cap.....						1							
Chase County Blue Flour.....												1	
Gehu Flint.....			3										3
Kiabab Flint.....													1
Cassia County Flint.....			1										3
Swadley.....													2
University 3.....												3	
Clarage.....												2	
Local Yellow.....												3	
Reid Yellow Dent.....												3	
Salzer Fodder.....							3		2				

Certain varieties, such as Minnesota 13 and Northwestern Dent, in some cases have been in the best class and at other times have given poorer results. This may indicate a narrower range of adaptation or less adaptability than that possessed by the varieties which have more often given good results, or it may indicate variability in the seed used.

A few varieties, such as U. S. Selection 160 and Amber Flint, have failed to give good results in any of the tests in which they have been included. This can not be attributed to poor seed, as that used germinated well and produced good yields in the localities where the seed was grown. The conclusion seems justified that the poor performance of these varieties was due to lack of adaptation to the conditions of the tests.

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HENRY S. GRAVES, Forester



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PROFESSIONAL PAPER

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SHORTLEAF PINE: ITS ECONOMIC IMPORTANCE AND FOREST MANAGEMENT.

By WILBUR R. MATTOON, *Forest Examiner.*

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ADAPTABILITY FOR FOREST MANAGEMENT.¹

Shortleaf pine possesses characteristics of growth which especially fit it for profitable forest management throughout a large part of the Eastern and Southern States. Over extensive areas from Maryland southward and westward to the Mississippi River it occurs as second growth, both in pure stands and mixed with hardwoods, and in the Gulf States and the central Mississippi Basin it forms a large proportion of the remaining virgin southern yellow pine. In a considerable portion of these regions shortleaf pine excels all other coniferous species in value and profitableness as a timber crop. It is one of the more important commercial pines and

¹ Frequent reference is hereafter made to Department Bulletin No. 244, "Life History of Shortleaf Pine," which treats in some detail of subjects of basic importance in the consideration of forest management such as size, age, soil, climatic demands, reproduction, and growth.

NOTE.—This bulletin is of value to those who are interested in the timber supply of the Eastern and Southern States, and in the management of tracts of shortleaf pine for their highest financial returns. It will be helpful to those in the regions covered desiring to restock denuded pine uplands by means of sowing and planting.

because of the following qualities promises to supply much of the future timber crop: (1) Quick and persistent growth, (2) vigor of reproduction and high sprouting capacity during youth when most susceptible to serious injury, (3) quick response to increase of light secured by thinning, (4) characteristically tall, straight, and clean trunk, (5) intermediate quality of the wood, which fits it for a wide range of uses, and (6) the gregarious habit of the species in pure stands, resulting in large yields of high-grade timber per acre.

NAME.

Shortleaf pine (*Pinus echinata* Mill.) is one of the important southern yellow pines.¹ It is also known by various other names, such as "yellow," "old field," or "rosemary" pine in the Piedmont region from Virginia to the Mississippi River; "hill" pine in Arkansas and Louisiana; and "two-leaf" and "spruce" pine in other regions. In the lumber market the wood is known mostly as shortleaf or yellow pine. In the Central Atlantic States shortleaf and loblolly are marketed under the trade name of "North Carolina" pine. In other regions loblolly is usually classed, without qualification, as shortleaf lumber, while shortleaf and, to a lesser extent, loblolly are more or less frequently graded and sold as longleaf pine.

In the following discussion of the annual cut, standing timber, lumber prices, and market it will be necessary to refer to the total southern yellow-pine cut as a basis, since there is no complete separation of the different species by the trade either in lumbering operations or in the general lumber market.

PRESENT SUPPLY.

The Bureau of Corporations in its report on the standing timber in the United States, published January 20, 1913,² states that in 1909 there were 152,100,000,000 feet of shortleaf (throughout the report shortleaf is used to include both shortleaf and loblolly) and 232,300,000,000 feet of longleaf pine, or a total of 384,400,000,000 feet of southern yellow pine, distributed as shown in Table 1.

¹ The other important pines making up the southern pine lumber are longleaf pine (*Pinus palustris* Mill.) and loblolly pine (*Pinus taeda* Linn.). Other southern pines of relatively small importance are slash pine (*Pinus caribæa* Morelet), sold and classed as longleaf; pond pine (*Pinus serotina* Michx.); and spruce pine (*Pinus glabra* Walt.).

² The most complete timber census available.

TABLE 1.—*Standing timber of southern yellow pine in 1909 for 11 Southern States.*[Publicly owned timber not included.]¹

State.	Shortleaf and loblolly pine.		Longleaf.		Total quantity.
	Quantity.	Distribution.	Quantity.	Distribution.	
	<i>Board feet.</i>	<i>Per cent.</i>	<i>Board feet.</i>	<i>Per cent.</i>	<i>Board feet.</i>
Alabama.....	12,400,000,000	8.2	25,600,000,000	11.0	38,000,000,000
Arkansas.....	26,000,000,000	17.1			² 26,000,000,000
Florida.....	900,000,000	.6	58,200,000,000	25.1	59,100,000,000
Georgia (part).....	13,200,000,000	8.7	18,500,000,000	8.0	31,700,000,000
Louisiana.....	15,200,000,000	10.0	52,500,000,000	22.6	67,700,000,000
Mississippi.....	14,800,000,000	9.7	47,600,000,000	20.5	62,400,000,000
Missouri (part).....	1,100,000,000	.7			1,100,000,000
North Carolina (part).....	22,700,000,000	14.9	2,900,000,000	1.2	25,600,000,000
South Carolina (part).....	14,600,000,000	9.6	4,600,000,000	2.0	19,200,000,000
Texas.....	22,500,000,000	14.8	22,400,000,000	9.6	44,900,000,000
Virginia (part).....	8,700,000,000	5.7			81,700,000,000
Total.....	152,100,000,000	100.0	232,300,000,000	100.0	384,400,000,000

¹ Bureau of Corporations, The Lumber Industry, Part I, p. 76.² In 1880, Sargent estimated merchantable stand of shortleaf in Arkansas at 41,000,000,000 feet, Tenth U. S. Census.

True shortleaf pine occurs in eight States besides those represented in the table, though in relatively smaller quantity. There are no accurate figures available of the relative proportion of loblolly and shortleaf. The best available estimate, based upon the distribution and the lumber production, places the amount of standing shortleaf at about 55 per cent of the combined amount of both species. On this basis there were in 1909 about 83,700,000,000 board feet in the States shown in Table 1. The report of the Bureau of Corporations for the same year showed that 4.1 per cent of the southern yellow pine was being cut annually.¹ This gives for the major part of the 11 most important States a remaining stand in 1913 of about 73,400,000,000 feet. To this must be added (1) the stand of shortleaf in the other eight States and the parts of Virginia, North Carolina, South Carolina, and Georgia not included in the above computation, (2) National Forest timber in Arkansas, and (3) the total increment or growth during the period, which may conservatively be placed at 1 per cent annually, after allowing for loss by fire and other causes. This gives a total of 80 billion board feet (Table 2), which is believed to be a conservative estimate of the present shortleaf-pine supply.

¹ There is reason to believe, however, that both longleaf and loblolly have been cut at a faster rate than shortleaf, because of their location over lowlands near the coast.

For the botanical and commercial range of shortleaf pine, see figure 1.

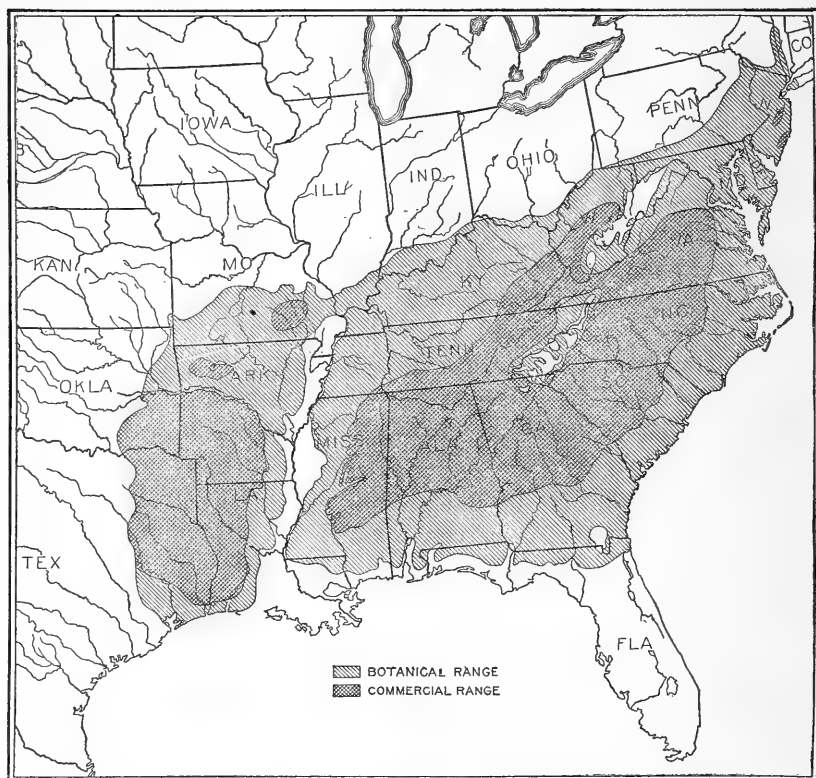


FIG. 1.—Botanical and commercial range of shortleaf pine.

TABLE 2.—Estimated total stand of shortleaf pine timber in the United States for 1913.

Region.	Standing short-leaf.	Region.	Standing short-leaf.
Eleven Southern States (6 States and parts of 5 States) ¹	<i>Board feet.</i> 73,400,000,000	Kentucky, Tennessee, and West Virginia ⁵	<i>Board feet.</i> 455,000,000
Virginia, North Carolina, South Carolina, and Georgia (parts) ² ...	1,144,000,000	New Jersey, Pennsylvania, Delaware, and Maryland ⁶	16,100,000
National Forests of Arkansas ³	1,608,900,000	Growth, 1910 to 1913, inclusive ⁷	3,000,000,000
Oklahoma ⁴	1,200,000,000	Total.....	80,824,000,000

¹ Based on Bureau of Corporations report "The Lumber Industry, Part I, Standing Timber." (Alabama, Arkansas, Florida, Louisiana, Mississippi, and Texas; parts of Georgia, Missouri, North Carolina, South Carolina, and Virginia) and annual cut at rate of 4.1 per cent.

² Reports of North Carolina Geological Survey; other States estimated on basis of comparative area with North Carolina and known character of stand.

³ Forest Service estimates for Arkansas (1,500,000,000 feet) and Ozark (108,900,000 feet) National Forests.

⁴ Rough estimate from general knowledge of area and character of distribution.

⁵ State report of Kentucky (195,000,000 feet) and two other States estimated on basis of comparison with Kentucky.

⁶ Rough estimates by States, based upon general character of distribution and regional studies by States or Forest Service.

⁷ Growth at rate of 1 per cent annually, after allowing for loss by fire, etc.

ANNUAL CUT OF SOUTHERN YELLOW PINE.

The annual cut of southern yellow pine has for many years far exceeded in total amount that of any other species or group of species in the United States. Of the seven leading groups shown in Table 3, yellow pine furnishes annually nearly as much as the combined output of all the other groups.

TABLE 3.—*Lumber cut of the seven leading woods in the United States, in the order of rank in production for 1913.¹*

Kind of wood.	Rank in production.	Lumber sawed.									
		Quantity (M feet b. m.).					Proportion of total cut of all species (per cent).				
	1913	1913	1912	1911	1910	1909	1913	1912	1911	1910	1909
Yellow pine ²	1	14,839,363	14,737,052	12,896,706	14,143,471	16,277,185	38.7	37.6	34.9	35.3	36.6
Douglas fir.....	2	5,556,096	5,175,123	5,054,243	5,203,644	4,856,378	14.5	13.2	13.7	13.0	10.9
Oak.....	3	3,211,718	3,318,952	3,098,444	3,522,098	4,414,457	8.4	8.5	8.4	8.8	9.9
White pine.....	4	2,568,636	3,138,227	3,230,584	3,352,183	3,900,034	6.7	8.0	8.7	8.4	8.8
Hemlock.....	5	2,319,982	2,426,554	2,555,308	2,836,129	3,051,399	6.0	6.2	6.9	7.1	6.9
Western pine.....	6	1,258,528	1,219,444	1,330,700	1,562,106	1,499,985	3.3	3.1	3.6	3.9	3.4
Cypress.....	7	1,097,247	997,227	981,527	935,659	955,635	2.9	2.5	2.7	2.3	2.1
Total ³		38,387,009	39,158,414	37,003,207	40,018,282	44,509,761	100.0	100.0	100.0	100.0	100.0

¹ Bureau of Census reports in cooperation with Forest Service, 1909-1912; Bureau of Crop Estimates in cooperation with Forest Service, 1913.

² All southern yellow pine except a very small amount of pitch pine and scrub pine in the Middle and North Atlantic States.

³ Total of all woods (about 40 species).

The cut of yellow pine ranged from 36.6 per cent of the entire cut of the country in 1909 to 38.7 per cent in 1913, when it amounted to 14,839,363 board feet. Of the eight States holding highest rank in 1913 in timber production, five owe their importance chiefly to their output of yellow pine, of which a large proportion is shortleaf. The production of yellow pine by States in 1913 is shown in Table 4.

TABLE 4.—*Production of yellow-pine lumber in 1913 by States.¹*

State.	Quantity.	Per-centage of total cut.	Num-ber of active mills report-ing.	State.	Quantity.	Per-centage of total cut.	Num-ber of active mills report-ing.
United States.	<i>Board feet.</i> 14,839,363,000	<i>Per ct.</i> 100.00	7,639	Virginia.....	<i>Board feet.</i> 810,362,000	<i>Per ct.</i> 5.5	1,023
Louisiana.....	3,092,375,000	20.8	299	Georgia.....	662,043,000	4.5	671
Mississippi.....	2,224,711,000	15.0	540	South Carolina.....	635,426,000	4.3	492
Texas.....	2,024,231,000	13.7	317	Oklahoma.....	120,860,000	.8	55
North Carolina.....	1,515,102,000	10.2	1,522	Maryland.....	65,143,000	.4	165
Alabama.....	1,395,059,000	9.4	744	Tennessee.....	60,137,000	.4	343
Arkansas.....	1,174,498,000	7.9	467	Missouri.....	57,023,000	.4	130
Florida.....	923,873,000	6.2	193	All others ²	78,520,000	.5	678

¹ Bureau of Crop Estimates and Forest Service, U. S. Department of Agriculture.

² Includes establishments distributed as follows: Connecticut, 24; Delaware, 35; Illinois, 3; Indiana, 2; Iowa, 2; Kentucky, 195; Maine, 25; Massachusetts, 39; New Hampshire, 3; New Jersey, 46; Ohio, 25; Pennsylvania, 193; Rhode Island, 6; Vermont, 3; and West Virginia, 86.

ESTIMATE FOR SHORLEAF PINE.

An estimate based on the assumption that the rate of cut of each species of southern yellow pine is approximately proportional to the stand would place the total lumber cut of shortleaf in 1913 at 22 per cent of the total southern yellow pine lumber cut, or 3,264,660,000 board feet.

Another estimate may be made by taking 4.1 per cent¹ of the estimated total stand in 1913 (Table 2). This would place the cut at 3,313,784,000 board feet of saw timber, a difference of only 1.5 per cent from the first estimate. A complete calculation would take into account the timber cut for poles, ties, piling, and other uses, although for some of these uses longleaf, because more resinous, is doubtless more extensively used. It is believed that about 3,500,000,000 board feet is a fairly good estimate of the present total annual cut of shortleaf pine.

Certain regional facts throw a good deal of light upon the question. For example, the percentage of shortleaf cut has rapidly increased in some sections of the South through the extension of steam logging roads into the hilly country. Many mills throughout Arkansas and adjoining States which formerly cut a good deal of loblolly pine from the low, flat country are now drawing much of their timber supply from shortleaf growing in the uplands. In the same manner shortleaf in the southern Appalachians is becoming accessible. Further, the cut of second growth in old field stands has increased by leaps during the past five years. In the central Atlantic States a region of heavy lumber production lies over the coastal plain where loblolly pine occurs in heavy stands. Larger areas of shortleaf, however, occur in these same States, although the cut is perhaps lighter than that of loblolly. The yellow pine cut from a large geographical region covering both the Piedmont and the lower slopes of the Appalachians consists almost exclusively of shortleaf pine.

THE WOOD.

PHYSICAL CHARACTERISTICS.

The wood of shortleaf pine is straight fibered, uneven textured with alternate hard and soft concentric rings, resinous, and moderately heavy, hard, and rapid growing. The heartwood is light reddish or orange in color and is clearly defined from the nearly white sapwood.

The weight of oven-dry shortleaf averages about 34 pounds per cubic foot. Air-dry wood (15 per cent moisture) averages about 38

¹ The rate at which southern yellow pine was being cut in 1909.

pounds, but varies in accordance with the moisture content, which ranges from 12 to 18 per cent. Green shortleaf in the log averages 45.5 pounds per cubic foot, with a moisture content of 31 per cent for heart and 88 per cent for sapwood. The loss of weight in drying amounts to about 25 per cent for the heartwood and about 60 per cent for the sapwood. In passing from a green to an oven-dry condition the wood shrinks about 12 per cent in volume, about one-third of which occurs in passing from the green to the air-dry (15 per cent) condition. The density of absolutely dry wood is variable, its specific gravity being from 0.48 to about 0.56.¹ This difference in density seems largely due to the varying conditions of growth over its wide geographic range.

In resin content shortleaf ranks lower than longleaf pine and about the same as loblolly, although all are variable, and the amount of difference has not been definitely determined. When the sapwood of shortleaf is freshly cut limpid resin oozes out freely. Occasionally the heartwood and normally the bases of all large limbs become highly impregnated with resin and furnish "lightwood" and "pine knots," extensively used for firewood. In fuel value shortleaf averages about 12 per cent below longleaf, of which 1 cord is approximately equivalent to a ton of coal. This is largely due to the difference in the average density of the two woods. For woods of the same weight per cord of the two species it is believed there is little difference, if any, in heat producing power.²

The wood varies somewhat in hardness, and in some regions is moderately soft. In its southern range it averages about as hard as longleaf pine when there is the same proportion of summer wood in the annual rings. The wood grown in the more northern regions or at higher altitudes in the southern region seems to be softer.

The width of the rings is greatest in early life. Ten to twelve rings to the inch is an average rate of growth during the middle period, say from 60 to 140 years. Within the individual annual ring, the transition from the spring to the summer wood is normally quite abrupt, giving the annual ring the appearance of two sharply defined lines or bands. In young and rapid-growing trees and in those growing where the summers are short, the transition is commonly more gradual.

Since the fibers are straight and do not interlock, the wood is straight grained, easy to split and but slightly subject to warp and check in drying. The wood is easily worked, may be given a good finish, and takes paint and wood preservative well. The contrast

¹ Latter figure not definitely determined.

² Forest Products Laboratory, Madison, Wis.

between the hard and soft layers in each annual ring gives the wood a very pleasing figured effect.

Even under a high-power microscope the woods of the important southern pines appear strikingly similar though not identical in structure. With a view of bringing out the features helpful in distinguishing the wood of shortleaf pine from the other important southern pines, a brief summary of characteristics is given in Table 5.

TABLE 5.—Average physical properties of the important southern pines.

Species.	Width of sap-wood.	Grain (comparative width and number of annual rings per inch). ¹	Resin content.	Weight per cubic foot.			Moisture content.			
				Green.	Air-dry (15 per cent moisture).	Oven-dry.	Green.		Air-dry. ²	
							Heart.	Sap.	Heart.	Sap.
Longleaf pine.	Inches. 2 to 3	Narrowest (14 rings).	Very abundant.	Lbs. 52.5	Lbs. 43.5	Lbs. 39.0	P. ct. 34.0	P. ct. 95.5	P. ct. 15	P. ct. 15
Slash pine...	3 to 6	Wide.....	do.....	52.5	45.0	41.5	32.5	84.0	15	15
Shortleaf pine	3 to 4	Intermediate (11 rings).	Moderate.....	45.5	38.0	31.0	31.0	88.5	15	15
Loblolly pine.	3 to 6	Widest (7 rings).	do.....	54.0	39.0	36.0	36.0	82.0	15	15

¹ Variable in all species so that rapid-growing longleaf might be taken for any of the others. This order prevails in the average.

² Heart and sap will ultimately reach the same moisture content if thoroughly air dried under the same conditions.

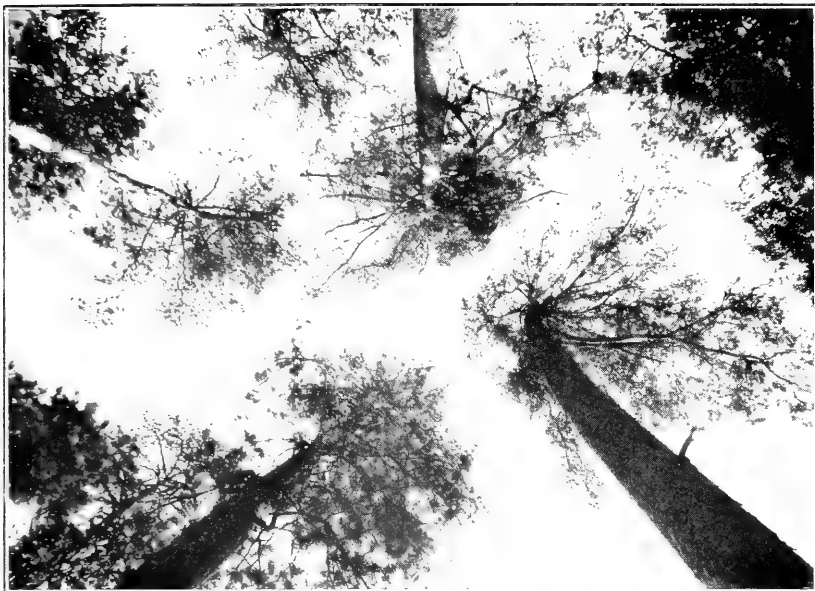
DURABILITY AND PRESERVATIVE TREATMENT.

Shortleaf pine is only moderately durable in contact with the soil. The presence of a large amount of resin, as in "light wood," is commonly thought to increase materially the natural durability of the wood. Sapwood is much less durable than heartwood; it can not ordinarily be expected to last over two or three years, while good heartwood may last seven or eight years. When not in contact with the soil or under conditions particularly conducive to decay, the wood has given good satisfaction.

By proper preservative treatment the durability of short-leaf pine can be very materially increased. Wood preservation is discussed in a number of publications, among which are Forest Service Bulletins 78, 84, 107, 118, and Circular 209.

MECHANICAL PROPERTIES.

The wood of shortleaf pine is strong and stiff and therefore very valuable for structural timber. It often contains the same number of rings per inch and is very similar in wood structure to longleaf pine, which holds first place among the southern pines used for this



F-13191A

FIG. 1.—VIEW THROUGH THE TOPS OF THE TREES SHOWN BELOW.



F-13192A

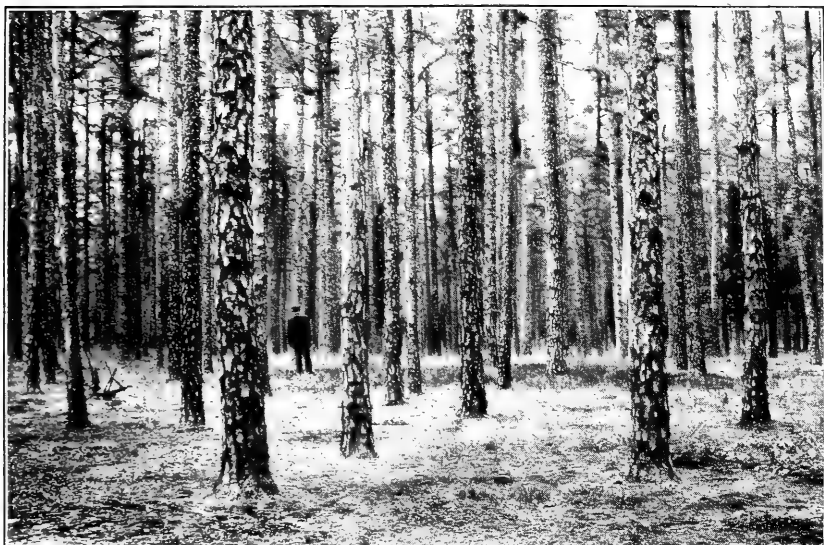
FIG. 2.—LOWER PORTION OF TRUNKS. TREES 160 YEARS OLD, 20 TO 28 INCHES IN DIAMETER, AND ABOUT 110 FEET IN HEIGHT.

TWO VIEWS OF A GROUP OF MATURE SHORLEAF PINE TREES, SHOWING THE NARROW CROWN AND STRAIGHT CLEAN BOLE TYPICAL OF THE SPECIES.



F-67319

GROSS CHARACTER OF SHORLEAF PINE IN CROSS SECTION.



F-15050A

FIG. 1.—A 70-YEAR-OLD SHORLEAF PINE STAND IN NEW JERSEY, WELL THINNED AND ALL THE THINNINGS FULLY UTILIZED.



F-14610A

FIG. 2.—WASTEFUL LOGGING OF SHORLEAF PINE IN SOUTH CAROLINA BY LEAVING MUCH HIGH-GRADE MATERIAL IN STUMPS. STRONG MARKET DEMAND FOR EVERYTHING DOWN TO 2 INCHES FOR CORDWOOD.

THINNING AND UTILIZATION OF SHORLEAF PINE.



F-13186A

FIG. 1.—SECOND-GROWTH LIMBY TOP LEFT ON ACCOUNT OF POOR GRADE OF TIMBER.



F-13185A

FIG. 2.—YIELD OF 18,000 BOARD FEET PER ACRE IN 60-YEAR-OLD SHORLEAF FOREST STAND.

LOGGING SECOND-GROWTH SHORLEAF PINE.

purpose. Other woods much used for structural timbers are Douglas fir, western hemlock, tamarack, Norway pine, loblolly pine, and western larch. Comparative tests of these in both a green and an air-seasoned condition, and for both structural sizes and small, clear, straight-grained pieces,¹ give shortleaf a relatively high place in all strength values, including bending, compression, and shearing. The values found in the various tests are shown in Table 6:

TABLE 6.—Average strength values of shortleaf pine, air seasoned, and green structural timbers with ordinary defects, and small, clear specimens cut from them.¹

Condition and size.	Rings per inch.	Horizontal shear per sq. in.	Bending.			Compression parallel to grain.			Com-pression perpen-dicular to grain.	Shear.
			Fiber stress at elastic limit per sq. in.	Modu-lus of rupture per sq. in.	Modu-lus of elas-ticity per sq. in.	Crushing strength at elastic limit per sq. in.	Crushing strength at maxi-mum load per sq. in.	Modu-lus of elas-ticity per sq. in.	Crushing strength at elastic limit per sq. in.	Shearing strength per sq. in.
Air seasoned struc-tural sizes.....	12.4	Pounds. 364	Pounds. 4,675	Pounds. 6,573	1,000lbs. 1,726	Pounds. 4,070	Pounds. 6,030	1,000lbs. 1,961	Pounds. 796	Pounds.
Small specimens ..	.....	.....	7,780	12,120	1,792	.....	6,380	.....	926	1,135
Ratio.....	.....	.....	60	54	96	.....	95	.....	86	.....
Green structural sizes.....	12.1	332	3,237	5,548	1,473	2,460	3,435	1,548	351	.....
Small specimens ..	.....	.....	4,350	7,710	1,395	.....	3,570	.....	400	704
Ratio.....	.....	.....	74	72	106	.....	96	.....	88	.....

¹ Tables 1, 2, and 10 to 15, Forest Service Bulletin 108, "Tests of Structural Timbers."

Though true longleaf pine averages heavier, stronger, and tougher, many pieces of shortleaf have greater density, strength, and toughness than the average longleaf pine. Also some longleaf pine lacks density and is weaker than the average of the other species, the density or dry weight of the wood being a much better criterion of the strength than the species.

USES.²

The general uses of shortleaf pine are as varied as those of longleaf and the two go together without preference or prejudice for many purposes. For heavy building and structural work, however, where the architect desires timber to sustain pressure and withstand shocks, longleaf is usually preferred. Because of a high degree of strength and elasticity, the heavier classes of shortleaf³ are being substituted for longleaf and are giving practically the same service. This recent

¹ Conducted by the Forest Products Laboratory, Madison, Wis.

² Based in part upon State cooperative wood manufacturing studies and Forest Service Bulletin 99, "Uses of the Commercial Woods of the United States: Pines," pages 17 to 20.

³ Timber having the same density as longleaf.

change is due chiefly to the recognition of the relation between the strength and the density of the wood.

Shortleaf pine is one of the chief house-building materials throughout the eastern and middle western United States. It is used both for house frames and for finish, including ceiling, weather boarding, wainscoting, baseboards, cornice, carved work, railing, panels, sash and doors, window and door frames and casing. The grain is handsome and shows well in natural finish or when stained. Because of its wearing qualities, pleasing appearance, and ready response to oils, wax, and other floor finishes and dressings, a good deal of shortleaf is made into flooring. Many of the large lumber mills of the South, particularly Louisiana, Arkansas, and Texas, advertise shortleaf pine as a specialty for finishing lumber and are producing it in great quantities and in many forms.

Furniture manufacturers find shortleaf an admirable wood for frames for couches, lounges, tables, large chairs, stands, and desks. It is also used for veneer in box, crate, and basket manufacture, and for excelsior and slack cooperage,¹ in agricultural machinery and tools, wagon bottoms and cart beds, hoppers, drawers, boxes, chutes, and compartments in fanning mills, corn shellers, grain drills, and in numerous other labor-saving machines and devices. Large quantities are used in car construction for roofing and siding. Railroad companies buy a large amount, of which the heavier kinds are used, with longleaf, in bridge and trestle work, and the rest for track timber, piling and crossties, usually treated with wood preservatives. As a material for ship and boat building, shortleaf has held a prominent place during the past two centuries not only along the coast within a hundred miles or so of the supply, but in practically all boat building ports east of the Rocky Mountains. It is worked into nearly everything of wood that is required in modern boat building.

The southern pines seem particularly adapted for the manufacture at low cost of strong, brown wrapping, or "kraft" papers.² The wood fibers are long and thick walled, and the wood has high specific gravity, implying large yields of pulp per cord. Several species of pine are now used in large quantities for the making of various kinds of wrapping paper, including kraft, and also for the manufacture of white book paper. Small timber and woods and mill waste are used for this purpose. Through recent development

¹ The quantities of shortleaf made into veneer, crates, baskets, excelsior, cooperage, crossties, and piling are not known because the southern yellow pines so used are not listed separately.

² The importance of this class of paper is shown by the fact that wrapping paper stands third among the paper products of the United States, the amount and value being less than that of news and book papers only. In 1909 the production of wrapping papers of all kinds aggregated 764,000 short tons, with a value of \$42,296,000. The value of wrapping paper imported in 1912 was \$846,500.

in Europe, especially Sweden and Norway, of the sulphate process, the superior quality of paper made from resinous woods has brought attention to shortleaf, along with the other southern pines, as an important source of pulp in this country.¹

With the use of either the sulphate or the soda process, the presence of knots, pitch pockets, and streaks, and remnants of decayed wood and bark is not very objectionable. Mill waste, consisting of slab edgings and trimmings, logs and tops left in the woods, and small logs which are now cut with little or no profit would supply a very large amount of raw material for pulp making. It costs more, however, to handle and prepare slabs and pieces of irregular shape than round pieces. Experiments² with longleaf pine have shown conclusively that it is well adapted for the manufacture of natural-color kraft pulps and papers, equal in quality to the imported and domestic kraft papers now on the market. Because of the close similarity of the wood of shortleaf to that of longleaf, it seems quite probable that further experiments will show a like suitability of shortleaf for this class of papers, except perhaps that it may produce less pulp per cord because of the difference in specific gravity of the two pines.

LUMBER INDUSTRY.

LOGGING AND MILLING.

The methods of logging and milling naturally show wide variations over a territory so extensive and representing so many different market conditions. Logging is still done by oxen to a considerable extent in the rougher lands of the southern Appalachians. Here the spring and fall months are usually chosen for operations. Steam skidders are not so much in use in logging shortleaf as in logging longleaf and loblolly pines, which belong to the lower level country. Teams do the majority of the hauling to the temporary logging spurs.

The small mill with a planer, located near some town center and producing timber for building and general construction for the neighborhood, and the portable mill are the most typical forms of manufacture in the great region of second growth in the eastern United States. Such mills usually have a daily capacity of 5 to 10 thousand feet. In the virgin pine country the mills more often represent a good-sized fixed investment and operating capital. The equipment includes logging railroads and buildings, machinery,

¹ Based upon Bulletin 72, U. S. Department of Agriculture, "Suitability of Longleaf Pine for Paper Pulp."

² Conducted by Forest Products Laboratory, Madison, Wis.

teams, and other logging appliances. With the retreat of the source of timber farther back into the hills many roads which at the start were purely railroad logging trams have been improved and organized as common carriers. Many mills in the Central South are hauling logs from 50 to 80 miles over their own rails, and some over 100 miles. As a rule the cost of handling prevents the separation of the rough milling from the finishing operations, and practically all of the mills in the Mississippi region manufacture large amounts of the standard forms of finished products. The larger mills commonly have two band saws, and the largest ones employ gang saws in addition. The capacities are mostly from 100 to 150 thousand feet in an ordinary working day, while the largest mills can turn out about 300 thousand feet a day.

COST.

The straight stem, the small crown, the clear and straight-grained character of the wood, and the gregarious habit of the tree make the cost of lumbering shortleaf pine relatively low. Large yields per acre afford opportunity for economy in method and equipment. On the other hand, the occurrence of shortleaf over rolling or hilly lands would tend to increase logging costs and the home of longleaf and loblolly over the low coastal plain affords easier logging and shorter hauls to seagoing transportation for the finished product.

The cost of manufacture in three representative regions—New Jersey, South Carolina, and Arkansas—is given below. A lumbering operation on private land within the Lebanon State Reserve, Burlington County, N. J., costs about 70 cents for cutting, \$3.50 for hauling logs 3 miles to the mill, and \$4 for milling. With the addition of 60 cents for depreciation the total cost was \$8.80 per thousand feet of rough lumber. The timber was mostly 70 to 110 years old.

In the uplands of South Carolina logging and sawing rough pine lumber by portable mills in small tracts often cost not more than from \$5 to \$7 per thousand feet. The mills are small and most of the output is roughly manufactured.

In the virgin shortleaf forest region from Alabama to Texas—for the past 10 or 15 years the greatest yellow-pine lumbering region of the United States—lumbering is on a comparatively permanent basis. In general, the cost of logging may be placed at from \$4 to \$7 per thousand feet and milling at \$6 to \$8, under average conditions and good management in the upland shortleaf regions. In this connection the itemized manufacturing costs of 30 mills cutting shortleaf timber in central and western Arkansas, shown in Table 7, will be interesting. The average cost of logging was \$5.47 and milling \$7.22, or a total cost of the finished timber aboard the car of

\$12.69. The labor is more largely negro than white, logging is in hilly country, with contract team hauling, and usually railroad logging spurs built up the larger depressions or drainage tributaries with rail hauls of 10 to 40 miles.

TABLE 7.—Average cost of manufacture of shortleaf pine by 30 mills.¹

Operation.	Range of costs per M board feet.	Average cost per M board feet.
Logging:	<i>Dollars.</i>	<i>Dollars.</i>
Cutting.....	0.28 to 1.00	0.63
Hauling with teams.....	1.00 to 4.56	2.24
Loading on cars.....	.17 to 1.50	.48
Railroad haul.....	1.00 to 5.49	1.94
Overhead charge.....	.08 to .25	.18
Total.....		5.47
Milling:		
Sawmill.....	1.10 to 3.00	1.74
Kiln.....	.11 to 1.50	.73
Planer.....	.64 to 3.00	1.46
Hauling with teams.....	.55 to 3.00	1.42
Loading on cars.....	.20 to .75	.40
Overhead charge.....	.35 to 3.82	1.47
Total.....		7.22
Total logging and milling.....		12.69

¹ Logging mostly in hilly country and milling by both large and small permanent mills in central and western Arkansas in 1912.

On the National Forests of Arkansas, portable mills with daily capacities of 10 to 20 thousand board feet saw the bulk of the timber. These mills cut about 2 million feet to each set, and thus greatly reduce the high cost of the log haul in rough country. Generally each company has its own planers at the most convenient railroad point, to which the rough lumber is hauled for distances of from 6 to 15 miles. In some sections smaller mills cutting 5 to 7 thousand feet daily are the prevailing type. The capital represented by these mills averages from \$5,000 to \$8,000 each. The ownership of the land is composite and the government timber is more or less cut up with small private holdings in various stages of development. The logging and milling costs do not vary widely and the present lumber prices are such as to allow net returns of 16 to 22 per cent on the full interest-bearing investment. A careful study of five companies operating on the Arkansas National Forest¹ shows an average total cost, exclusive of stumpage, of \$11.07 f. o. b. cars for finished lumber. The costs shown in Table 8 are for one of the representative mills working where the timber is scattered in the hilly portions of western Arkansas. The cost of operation, \$10.70 per thousand feet, was next to the lowest for five companies in a region where the highest cost was

¹ Reports by Messrs. Dorr Skeels and Quincy Randles, of the Forest Service, spring of 1913.

about \$11.50. The figures indicate the various factors considered in logging and manufacture and the cost of operations in cutting 16 million feet of shortleaf pine during a period of 4 years with 10 settings of a mill having a daily capacity of 20 thousand feet. The timber runs 2 to 3 logs per tree and 8 to 10 logs per thousand, and occurs mostly either in small groups or widely scattered over an area of 18,000 acres divided by a range of low mountains into two natural logging units. The lumber haul to the railroad is from 5 to 11 miles.

TABLE 8.—*Itemized cost of manufacturing shortleaf pine on the Arkansas National Forest.*

	Cost per thousand board feet.
Cost of rough lumber on kilns at sawmill (distributed below)-----	\$5.47
Investment, depreciation, interest, and labor on logging and sawmill:	
Two sawmills fully equipped and set up, \$6,000 at 7 per cent depreciation-----	\$0.10
Sixteen logging teams, wagons, harness, and chains, \$8,000 at 17 per cent depreciation-----	.30
Moving sawmill, 10 sets at \$300, and 100 miles logging roads at \$30 per mile, average yearly investment of \$1,500----	.38
Total investment of \$15,500: interest at 6 per cent on \$13,070 ¹ -----	.19
Felling, bucking, and brush disposal-----	1.00
Labor, team maintenance, bucking, loading, log haul 1½ miles-----	2.00
Labor, sawing, and smoke-kiln drying-----	1.50
Lumber haul, 8 miles partly over rough roads, 3 trips in 2 days-----	3.13
Planer (distributed as follows: chargeable against 60,000,000 feet annual cut)-----	1.47
Investment—	
Planer, \$10,000; real estate, \$3,000; lumber in yards, \$4,500; lumber at mills, \$1,500; accounts receivable, \$6,000; total, \$25,000. Interest on \$25,000 at 6 per cent, depreciation on \$10,000 (value planer) at 7 per cent----	.37
Labor—	
20 men per day (5 counted as lay-off time) at \$1.75-----	1.10
General overhead charges: Taxes, \$600; insurance, \$750; superintendence, \$1,200; bookkeeper, \$900; supplies and repairs, \$600; and general office expenses, \$200; total, \$4,250-----	.63
	10.70

The average cost of manufacture, exclusive of stumpage, was \$11.07 for five large portable mills averaging 3.5 million feet annually and representing an interest-bearing capital of \$33,300 each. This cost of operation plus stumpage averaging \$2.59 gives the total

¹ Fifteen thousand five hundred dollars minus one-half the investment retired in 3 years, or \$2,430, equals \$13,070. Mill cutting 4,000,000 feet per year.

cost of finished lumber as \$13.66. At current selling prices (April, May, 1913) of \$15.75, this yielded a net profit of \$2.09 per thousand feet, or total annual net earnings of \$7,315. This represents clear profits of 21 to 24 per cent, or an average of 22 per cent, for the five companies.

WASTE.

The degree of utilization in the logging, manufacture, and general use of shortleaf pine varies widely. On the whole, the utilization is comparatively close throughout its range. In the uplands of the coastal Atlantic and Gulf States practically all of the product finds a ready market. The poorer class of timber is used locally, and the day of clearing off lands by destructive fires ceased in this region long ago. Almost paradoxical, however, is the waste in one particular feature of logging in some of the more progressive regions. As an illustration, in Pickens County, in the upper Piedmont of South Carolina, stumps of mature shortleaf pine were cut from 20 to 34 inches in height (March, 1913), where everything of the smaller sizes down to 2 inches in diameter was being corded and shipped by rail for fuel. Thus, clear and high-priced timber was being left where there was a paying market demand for even the small topwood. The cause for this condition was given by the operator as the impossibility of changing the old-time habits of the negro labor of cutting high stumps. Two stumps, 28 and 30 inches high, shown in Plate III scaled a total of 38 board feet (Doyle log rule) above a stump height of 12 inches, and were worth \$0.19 at a stumpage rate of \$5 per thousand feet.¹ Measurements on an average acre gave 30 stumps containing an average of 9 board feet each above a maximum stump height of 12 inches, or a value of \$1.35 per acre. This represents practically a clear loss due to careless logging of not less than \$270 on the tract of 200 acres.

In contrast, the operators of the Mississippi Valley region are cutting to a maximum stump height of 12 inches, and small trees up to 15 inches in diameter are taken mostly at 8 to 10 inches. On the other hand, in very many cases they do not take the log or logs in the crown above about the second limb. Top diameters of 12 to 16 inches were common in representative mature cuttings in Pike County, Ark., in the fall of 1912. In a well-stocked stand, 150 years old, 380 logs were taken and 100 logs left per acre in the tops because of the lower grade of timber. The top logs taken ranged from 16 down to 9 inches and averaged 11.6 inches in diameter at the small end. The diameters of the top logs left in the woods averaged 9.8 inches and ranged from 13 down to 8 inches. The number of logs taken and left per acre, and

¹ A conservative price for clear material in butt logs.

their volume and value at assigned stump prices in logging well-stocked stands of various ages, are shown in Table 9.

TABLE 9.—*Utilization and waste in logging well-stocked forest stands of short-leaf pine in Arkansas.*¹

Age.	Logs taken.								Logs left.											
	Logs per acre.			Diameter inside bark of top log.			Scribner.		Doyle.		Logs per acre.			Diameter inside bark of top log.			Scribner.		Doyle.	
	Maximum.	Average.	Minimum.	Contents. ²	Value at \$3 per M.	Contents. ²	Value at \$3 per M.	Maximum.	Average.	Minimum.	Contents. ³	Value at \$1.50 per M.	Contents. ³	Value at \$1.50 per M.						
Yrs.	In.	In.	In.	Bd.ft.	Dolls.	Bd.ft.	Dolls.	In.	In.	In.	Bd.ft.	Dolls.	Bd.ft.	Dolls.						
65	160	15	9.3	6	7,845	23.54	5,815	17.44	45	10	8.0	7	760	1.14	441	0.66				
75	270	11	9.1	7	14,580	43.74	10,856	32.57	75	9	7.8	7	1,160	1.74	637	.96				
150	380	16	11.6	9	48,150	144.45	40,290	120.87	100	13	9.8	8	2,640	3.96	1,912	2.87				
160	470	15	11.1	8	53,010	159.03	45,090	135.27	70	10	8.7	8	1,840	2.76	1,208	1.81				
170	229	16	11.3	7	23,619	70.36	20,133	60.40	63	12	8.6	7	1,680	2.52	1,107	1.66				
180	220	21	15.0	8	39,780	119.34	35,906	107.72	84	15	9.7	8	4,096	6.14	3,197	4.80				

¹ Measurements taken in November, 1912, on seven plots representing six different age classes.

² Ten per cent deducted for defects in logs taken.

³ Twenty per cent deducted for defects in logs left.

Under the best conditions of market the utilization of top logs runs higher than is shown in Table 9. Where there are log hauls of 50 to 90 miles over railroads, now necessary for many of the larger mills, there is small profit in manufacturing the lower grades. In the flat, easily logged regions, straight and clear boles are taken for saw timber down to as low as 5 inches, and sometimes less. In much private lumbering practically everything straight and clear is taken. As a northern Louisiana operator said, "we take everything that will make two slabs and sawdust." This policy, which removes the chief basis for a second cut, is being pursued for the alleged reason that fire gets what the lumberman leaves. There is a wide difference of opinion in regard to the subsequent damage and loss by fire. Mr. L. J. Witherspoon, Womble, Ark., found by counts that in five years heavily cut tracts lost by all the combined destructive agencies only from 5 to 15 per cent of the trees above 3 inches in diameter.

Inspection and grading that would include as merchantable lumber short lengths down to 4 feet and provide for odd lengths throughout up to 24 feet would result in a very large reduction of present milling waste. Short lengths of the clearest lumber in the tree in the form of slabs now go to making steam because of the present limitations; for the same reason many logs are now left in the tops. In most cases this is the result of haste and a desire to secure quantity rather than quality through careful grading. Better utilization would mean also remodeling plants and adding machinery for remanufacturing the product. The utilization of waste wood by

chemical methods is making rapid progress, particularly in the resinous woods. Stumps and knots of shortleaf often become highly impregnated with resin, though in general its low resin content makes it less valuable than longleaf for use in resinous-wood distillation.

GRADES.

The tall, clean bole of shortleaf pine and relatively low susceptibility to injurious fungi, permit a high percentage of the upper grades of lumber. In the region of heavy production of virgin pine the rough lumber from the saw is commonly thrown into the five grades of clear, and Nos. 1, 2, 3, and 4 common. The lowest qualities come from the small portable sawmills in the farming districts, where the cut is mostly from second growth or culled land. The great bulk of the cut of shortleaf in Mississippi, Alabama, and Georgia as well as Arkansas and Louisiana is probably well represented by the third distribution given in the following table:

TABLE 10.—Average mill cut by grades of shortleaf pine west of Mississippi River.¹

[Percentage of total cut.]

Locality.	Grades of rough lumber.				
	Clear stock "B and better."	No. 1 common.	No. 2 common.	Nos. 3 and 4 common.	Total.
Best timber in most favorable region (Clark County, Ark.).....	<i>Per cent.</i> 36.9	<i>Per cent.</i> 45.9	<i>Per cent.</i> 11.0	<i>Per cent.</i> 6.2	<i>Per cent.</i> 100
Good timber along Iron Mountain R. R. (Arkansas). Good timber in hilly shortleaf region. Average for 7½ months, March 1 to October 15, 1912 (Pike County, Ark.).....	35	40	19	6	100
Small portable mills in farming districts (western Arkansas).....	32	39.9	17.3	10.8	100
	20	48	29	3	100

¹ Based upon information furnished by lumber companies in the region covered.

In general shortleaf cuts from 30 to 35 per cent of clear stock ("B and better"), 40 to 50 per cent of No. 1 common, 15 to 30 per cent of No. 2 common, and 5 to 10 per cent of the two lower grades of common lumber. On account of defects which develop later somewhat less is actually marketed.

In cutting the second-growth stands in the Piedmont region, little attention is given to grading by the small operators. Larger operators, however, find it profitable to grade the stock from the saw. Often two grades, sap and heart pine, are roughly made by the small mills with an assigned difference of \$5 to \$6 per thousand feet in price.

In the Mississippi Valley the product is graded by the rules of the Southern Pine Association, whose specifications refer closely

to defects, without qualifications in regard to heart. The rules of the North Carolina Pine Association and the Georgia-Florida Sawmill Association govern the bulk of the eastern business. The chief shortleaf pine products of the larger mills and the various grades of each are: Dressed finishing, 3 grades and specials; flooring, 12 grades; ceiling, 4 grades; wagon bottoms, 2 grades; drop siding and bevel siding, 4 grades; partitions, 4 grades; molded casing and base, window and door jambs, 3 grades each; common boards, ship lap, and barn siding, 4 grades; grooved roofing, nearly same as No. 1 of preceding; fencing, 4 grades; dimension and heavy joist, 3 grades; No. 1 common timbers; lath, common and patent; and pickets.

MARKET.

Much confusion exists in the eastern markets regarding the names under which southern pines are sold. Those in use represent essentially, in different degrees, the qualities of weight, strength, and grain or width of annual rings. In general, the names "longleaf" and "shortleaf" are used to designate the harder and softer qualities of southern pine lumber, and this is broadly justified by differences in the species. Longleaf averages the heaviest and closest grain. Shortleaf is clear lumber of high quality and an intermediate number of rings per inch and loblolly has very wide annual rings and thick sapwood. Lumber sold as longleaf often contains more or less of the heavier kinds of shortleaf. Rapid growing longleaf and shortleaf both have wide annual rings and thus might be classed as loblolly. There is no complete separation in the lumber market.

A large amount of the shortleaf lumber produced—estimated by some at as high as one-half—is sold by the manufacturers direct to large consumers, such as railroads, manufacturers of railroad equipment, and those engaged in the construction of buildings and other structures requiring material in large quantities. The remainder of the output is mostly sold direct to wholesalers, brokers, and retailers. Many of the large manufacturers are also retailers, either directly or indirectly, through subsidiary companies. A very large amount of the shortleaf lumber goes into further manufacture and finds its market in the wood-using industries of the various States.

The market for shortleaf pine includes practically all of the United States east of the Rocky Mountains. Within this region, the districts of lightest use are the upper Lake States and New England. In the former region white and red pine and in the latter region loblolly pine, shipped by cargo from the Atlantic coastal plain, are used in large amounts. According to the wood-using industry reports,¹ little shortleaf reaches Massachusetts; Maine uses

¹ This and the following statements are based upon various wood-using industries bulletins published by the individual States in cooperation with the Forest Service.

more than 10,000,000 feet annually of longleaf and loblolly, but practically no shortleaf; in Iowa, shortleaf is second only to white pine in total quantity used; in Illinois in 1912 it stood second in car manufacture, first for sash, door, and blind, and also box manufacture, and entered into the leading classes of wood products. The most intensive market area lies from New York through the north-eastern, central, and southern prairie States. The best available estimate of the quantity of shortleaf further manufactured by the wood-using industries of the United States annually during the period of 1910 to 1912 is, in round figures, 3,500,000,000 board feet (Table 11), valued at about \$52,740,745 f. o. b. factory. Of this amount about 2,500,000,000 feet were converted into planing-mill products, and the balance largely used for sash, doors, blinds, and general millwork, boxes and crates, car construction, agricultural implements, vehicles and parts, fixtures, furniture, and shipbuilding.

TABLE 11.—*Quantity and value of shortleaf pine used annually by the wood-manufacturing industries of the United States.*¹

Industry.	Quantity used.	Average value per M feet.	Total value.	Industry.	Quantity used.	Average value per M feet.	Total value.
Planing-mill products and general millwork	<i>Board feet.</i>	<i>Dolls.</i>	<i>Dolls.</i>	Fixtures.....	<i>Board feet.</i>	<i>Dolls.</i>	<i>Dolls.</i>
Sash, doors, and blinds.....	2,501,189,960	12.26	30,653,669	Furniture.....	9,864,765	30.34	299,298
Boxes and crates...	327,830,625	23.30	7,639,295	Shipbuilding.....	7,651,800	18.38	140,645
Car construction...	349,094,714	15.52	5,419,004	Miscellaneous ²	5,173,762	23.88	123,531
Agricultural implements.....	212,913,493	25.02	5,327,034		79,401,264	23.05	1,830,498
Vehicles and parts...	37,132,070	26.84	996,653	Total.....	3,544,751,908	14.88	52,740,745
	14,499,455	21.46	311,208	Total exclusive of planing-mill products.....	1,043,561,943	21.17	22,087,076

¹ This is a tentative table, compiled from the various State wood-using industry reports, published by the State organizations and lumber-trade journals, in cooperation with the Forest Service. Figures are for the period 1910 to 1912, or an average about 1911. Although reported as true shortleaf, it seems likely that the amounts are somewhat high because of the tendency to include some other material than shortleaf under this head.

² Very low average due to extensive planing-mill industry of producers in Arkansas, Louisiana, Alabama, North Carolina, Mississippi, and Texas, where supplies are secured without cost for transportation.

³ Includes chiefly sporting and athletic goods, machine construction, caskets and coffins, wooden ware and novelties, printing material, kitchen cabinets, refrigerators, elevators, frames and molding, tanks, and silos.

LUMBER PRICES.

The average mill-run price of shortleaf pine lumber does not differ much from that of the other southern yellow pines. In the Gulf States it holds closely to that of longleaf and in the central Atlantic States to loblolly. The factors which govern this more than anything else are location, cost of transportation to the larger markets, and average size of mill output. For example, in 1912 the average mill-run of "North Carolina pine" was \$14.22, while yellow pine in Arkansas was \$14.78. Mississippi, where the percentage of longleaf in the cut is as high as anywhere, showed an average mill-run

value of \$14.80, or only 2 cents higher than Arkansas, where no longleaf occurs. Below is shown the average wholesale mill-run value at the mill for southern yellow pine lumber from 1899 to 1914, inclusive.¹ Shortleaf was a heavy contributor and its fluctuations have doubtless been quite similar.

1914-----	\$14.19	1911-----	\$13.87	1908-----	\$12.66	1904-----	\$9.96
1913-----	15.76	1910-----	13.29	1907-----	14.02	1899-----	8.46
1912-----	14.36	1909-----	12.69	1906-----	15.02		

From 1908 to 1913 a gradual advance in price occurred in common with nearly all coniferous woods. From an average value in 1901 of approximately \$9 the price rose to \$13.87 in 1911, an increase of 54 per cent in 10 years. The advance in price was strongly upward to the year 1906, when the values reached a high point. Between 1908 and 1913 the advance in price was steady but more gradual, with rather marked variation during 1914 and 1915.

TABLE 12.—*Cost of longleaf, shortleaf, and loblolly lumber used by the wood-manufacturing industries of 16 States.*¹

Group and State.	Average cost per M board feet f. o. b. factory.			Group and State.	Average cost per M board feet f. o. b. factory.		
	Longleaf.	Shortleaf.	Loblolly.		Longleaf.	Shortleaf.	Loblolly.
Northeastern States:	<i>Dollars.</i>	<i>Dollars.</i>	<i>Dollars.</i>	Southern States:	<i>Dollars.</i>	<i>Dollars.</i>	<i>Dollars.</i>
Connecticut.....	36.10	23.32	27.00	Florida.....	11.66	11.60	11.77
Delaware.....	31.46	18.08	15.56	Georgia.....	13.30	13.03	10.03
Maine.....	35.12	31.00	29.71	Mississippi.....	11.66	11.66	11.24
New Hampshire.....	33.70	28.86	29.99	Texas.....	12.71	12.64	11.51
New York.....	31.49	27.34	20.77	Average for Northeastern States.....	33.30	27.52	25.21
Vermont.....	31.91	36.50	28.21	Average for Central States.....	24.79	22.05	21.49
Central States:				Average for Southern States.....	12.33	12.23	11.14
Iowa.....	28.04	29.05	27.45	Average for all States represented.....	23.47	20.60	19.28
Illinois.....	28.69	26.07	27.72				
Ohio.....	26.26	25.75	18.32				
Tennessee.....	20.23	16.18	.....				
Virginia.....	20.26	13.26	12.77				
West Virginia..	25.26	21.99	21.20				

¹ Compiled from various State wood-manufacturing industry reports in cooperation with the Forest Service. Figures must be considered as approximate since there is no accurate separation of the species in the market.

The lowest average price of pine used by the wood manufacturing industries shown in Table 12, occurs in the large lumber-producing Southern States, where most of the big sawmills manufacture planing-mill products, obtaining their supplies without transportation charges; also a number of these industries use logs, wholly or partly, and reported cost on these instead of on lumber. An increasing

¹ Prices for 1913 are based upon average prices during the last three-quarters of the year from large representative mills in the States of Georgia, Florida, Alabama, Mississippi, Louisiana, Arkansas, and Texas. The 1914 figures are based upon reports of similar representative large mills in 10 States from Virginia to Texas for the complete year. The earlier prices represent reports submitted by miscellaneous operators, both large and small. A question whether these prices are legitimately comparable with the 1913 and 1914 figures may properly be raised.

price will be noted for States more distant from the region of production. The figures thus represent only roughly the average cost of lumber of the various species in the different States and regions shown.

STUMPAGE VALUE.

The value of shortleaf pine stumpage is in general a little below that of longleaf in the Gulf States and above loblolly in the Central Atlantic States. The slightly higher market value of longleaf pine lumber and the distribution of shortleaf pine over the more hilly lands have a tendency to make the stumpage value for shortleaf slightly lower than for longleaf pine. The closer proximity, however, of shortleaf to the markets of the Central and Middle Western States gives it an advantage.

The purchase of "timber rights" in the North Carolina pine region by one company from 1896 to 1908, shown in figure 2, illustrates the

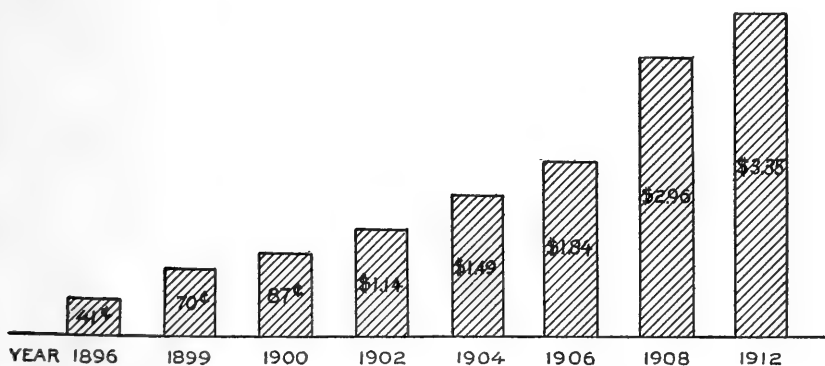


FIG. 2.—Cost of yellow-pine stumpage to one company in North Carolina, from 1896 to 1908 ("The Lumber Industry," Bureau of Corporations, p. 23), and estimate for 1912 (based on average price for North Carolina in 1912, plus increase of price in 1909 over average value for State).

general upward movement of yellow pine stumpage in the eastern market.¹

In the central Mississippi Valley region the stumpage values are not essentially different from those in North Carolina. In Arkansas stumpage for virgin timber was worth, in round figures, 40 cents in 1890, \$1 in 1900, \$2.50 in 1907, at the crest of the year's prices, and in 1913 was reported at \$3 to \$4. Second growth in abandoned fields reaches diameters of 10 to 14 inches in fifty years, with yields of 10 to 20 thousand feet. Such tracts, if located near good local markets with railroad facilities, have stumpage values ranging from 50 cents up to about \$1.50, but otherwise values are small, ranging down to a few cents, mostly a potential or holding value.

¹ Prices for 1896 from "The Lumber Industry, Part I," Bureau of Corporations, p. 23.

The demand for standing shortleaf pine timbers in Arkansas is indicated well by the prices offered for Government timber on the Arkansas National Forest. The timber is located mostly in the rougher and more inaccessible portions of the State, and is cut up somewhat by small private holdings. Timber sales in 1914 under competitive bids in this rough region were made at prices ranging from about \$2.25 up to \$3 per thousand feet.

The stumpage values for shortleaf pine were collected by the Forest Service for the year 1912 from the various States in the form both of reports of sales actually made and estimates of buyers and others qualified to know market prices. The average values reported by lumber companies in 1912 and in 1907 for various States are shown in Table 13.

TABLE 13.—*Stumpage value of southern yellow pine in 1912, with comparison of average values in 1907.*¹

Group and State.	1912.						Average value in 1907.		Rate of increase in 5-year period.	
	Average value.		Range of values.		Basis: Number of reports.		Average value.	Basis: Number of reports.	Estimates.	Sales.
	Based on estimates.	Based on sales.	Based on estimates.	Based on sales.	Estimates.	Sales.				
Northern Atlantic:									<i>P. ct.</i>	<i>P. ct.</i>
Delaware.....	\$5.19	\$4.50	\$4.00-6.50	\$4.00-5.00	8	2				
Maryland.....	5.43	5.11	2.00-8.00	3.00-7.50	26	9	\$4.33		10	
New Jersey.....	4.25	3.00	3.00-5.00	3.00-3.00	4	1	4.20		5	
Pennsylvania.....	6.12	5.50	3.00-12.00	3.50-10.00	52	16	5.30		37	
Average for group.....	5.25	4.53					4.61		13.9	1.7
Western Appalachian:										
Kentucky.....	3.36	4.00	1.00-8.00	4.00-4.00	21	2	2.36		12	
Tennessee.....	3.22	3.50	1.50-5.00	2.00-5.00	48	24	2.60		15	
West Virginia.....	3.25	4.00	2.00-4.00	4.00-4.00	6	2	3.32		14	
Average for group.....	3.28	3.53					2.76		18.8	38.8
Southern Atlantic:										
Georgia.....	2.79	2.68	1.50-5.00	1.50-5.00	90	38	2.51		43	
North Carolina.....	3.07	3.07	1.50-6.00	1.50-7.00	167	79	2.73		49	
South Carolina.....	2.97	2.99	1.00-6.00	1.75-5.00	71	29	2.45		25	
Virginia.....	3.70	3.85	1.00-6.00	2.00-5.50	37	17	2.99		60	
Average for group.....	3.13	3.02					2.67		17.2	13.1
Gulf:										
Alabama.....	2.39	2.32	1.00-5.00	1.00-5.00	122	56	2.29		45	
Arkansas.....	2.57	2.54	1.25-5.00	1.50-5.00	69	40	2.45		65	
Florida.....	2.96	3.01	1.50-6.00	1.75-6.00	80	53	2.91		40	
Louisiana.....	3.86	3.64	1.50-7.00	1.50-6.00	57	34	3.20		32	
Mississippi.....	3.44	3.59	1.00-6.50	1.00-6.50	60	38	2.78		41	
Texas.....	2.98	3.10	1.00-5.00	1.00-5.50	65	43	2.22		35	
Average for group.....	3.03	3.03					2.64		14.8	14.8
Oklahoma.....	1.84	1.80	1.00-4.00	1.00-3.00	11	5	1.13		4	
Missouri.....	2.30	2.50	1.00-6.00	1.50-6.00	35	14	2.54		13	
Average for Oklahoma and Missouri.....	2.07	2.15					1.84		12.5	16.8

¹ Figures for 1912 based upon reports of estimates and sales received from lumber companies; the 1907 values are based upon estimates.

In Missouri, Kentucky, West Virginia, and Pennsylvania, neither longleaf nor loblolly pines are known to occur, while in three others—New Jersey, Tennessee, and Oklahoma—loblolly is present only in very small areas. In all except New Jersey and Pennsylvania, shortleaf is the principal yellow pine and dominates the market.

The stumpage value of yellow pine can best be studied by natural groups of States, i. e., those having generally similar density and areas of stands. Thus New Jersey, Pennsylvania, Delaware, and Maryland led with an average stumpage of \$5.25 in 1912, as compared with \$4.61 in 1907. (Table 13.) West Virginia, Tennessee, and Kentucky came next in order with values of \$3.28 and \$2.76 for the same years. The group comprising Virginia, North Carolina, South Carolina, and Georgia averaged \$3.13 and \$2.67, respectively. The States of Alabama, Florida, Mississippi, Louisiana, Arkansas, and Texas, the principal producers of virgin yellow pine, averaged \$3.03 for 1912 and \$2.64 for 1907. The low figures of \$2.07 and \$1.84 for Missouri and Oklahoma are probably due to the low yield and quality of pine in Missouri and special features of timber ownership in Oklahoma. The higher stumpage value in the North Atlantic States is undoubtedly due to the strong local demand near large centers of population. Stumpage values are highest in the North and decrease with striking regularity all the way to the southern and western extremity of the yellow-pine belt. The highest rate of increase in value during the period of five years ending in 1912 occurred in the middle of the zone of distribution.

The yellow-pine timberlands of the South constitute one of the two chief timber supply regions of the United States. With an increasing population and diminishing timber supply, the speculative holding of timberlands has become general, and, except for the periodic declines of a temporary character, the general movement of stumpage values of shortleaf in common with the other southern pines is likely to continue in an upward direction.

The practice of cutting and burning timber in clearing lands is still prevalent in some of the southern and Mississippi Valley States. In some of the more remote sections tracts of 20 to 50 acres of pure stands containing from 5 to 25 thousand board feet per acre of second-growth pine are not infrequently cut without thought or comment. The larger trees are usually girdled and the smaller ones cut and burned. Thus are destroyed many stands, the accumulated timber growth of several decades, which would, if left for relatively few years, bring good stumpage prices.

ESSENTIALS OF FOREST MANAGEMENT.

Forest management aims to make the forest continuously productive of the largest quantity and at the same time the most useful or valuable quality of timber. It deals essentially with second growth, including in the South the so-called "old field" stands. The increasing scarcity of virgin timber is daily developing new uses for second growth, and stands formerly considered of no value are now becoming commercial assets. Owners will find it more and more profitable, therefore, to employ intensive methods of handling timberlands.

Under forest management, it is necessary first of all to protect the growing tree crop against fire and other harmful agencies. The age at which the stand should be cut, or the period of rotation, must be determined in advance upon the basis of the size and kind of wood desired. The tree density, or amount of growing stock on the ground, strongly influences the growth and should be regulated by thinning or artificial restocking. Cutting so as to secure complete natural reproduction is of great importance.

PROTECTION.

FIRE.

Owners of southern pine lands now realize that enormous loss and injury result every year from forest fires. They will be interested therefore in methods of preventing fires as far as is possible and of controlling at an early stage those which are started. To be sure, shortleaf pine regenerates vigorously by sprouts during early life when subject to greatest fire injury. The injury caused to older trees, however, by even a surface fire is very often recorded in the entrance of destructive fungi, or "punks," through the fire scars, and retarded growth, due to the removal of the protective layer of leaf litter ("pine straw") and soil enriching humus. The loss of trees by repeated fires during a period of 30 or 40 years and consequent reduction in the yield is surprisingly large. The person starting a fire which spreads to his neighbor's forest is rightfully held responsible for the destruction of property. The best protection lies in the hearty cooperation of all landowners and communities in the enforcement of efficient State fire laws. When rightly planned and constructed, fire lines are very helpful in protecting growing timber, and are proving effective in the yellow pine on the National Forests of Florida and Arkansas. A double furrow stops slowly burning surface fires and is a good base from which to fight others. Fire lines are best constructed by opening one or more furrows on each side of a strip 4 to 8 yards wide and, in favorable weather burning over the intervening ground.



F-13222A

FIG. 1.—ENCROACHMENT OF SHORTLEAF ON SUCCESSIVELY ABANDONED PORTIONS OF COTTON FIELD. STANDS OF SIX DIFFERENT AGES.



F-20687A

FIG. 2.—VERY DENSE STAND OF 9-YEAR-OLD SEEDLINGS, 42,000 TREES PER ACRE. NOTE CLOSE RELATION BETWEEN DENSITY AND DEVELOPMENT.



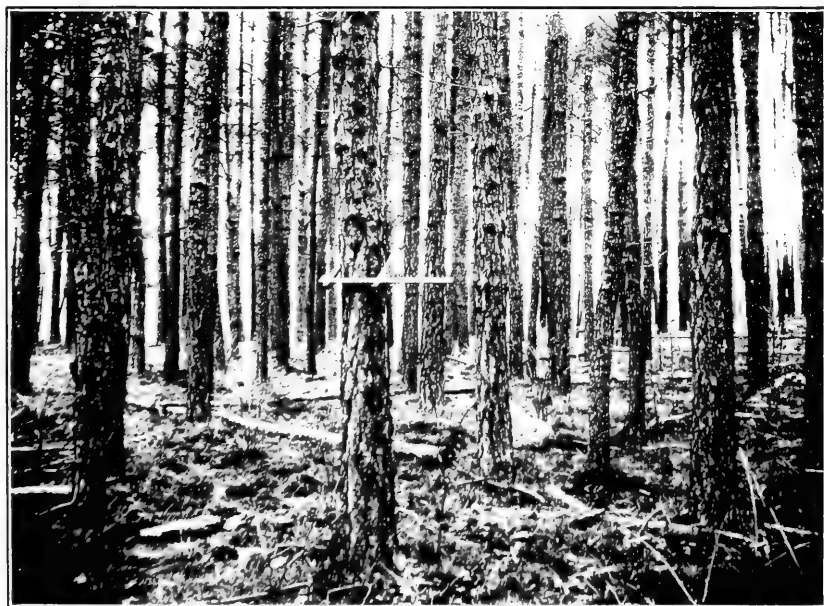
F-67318

TOP ENDS OF SUCCESSIVE 10-FOOT LOGS OF
52-YEAR-OLD SHORTLEAF PINE. BREAST-



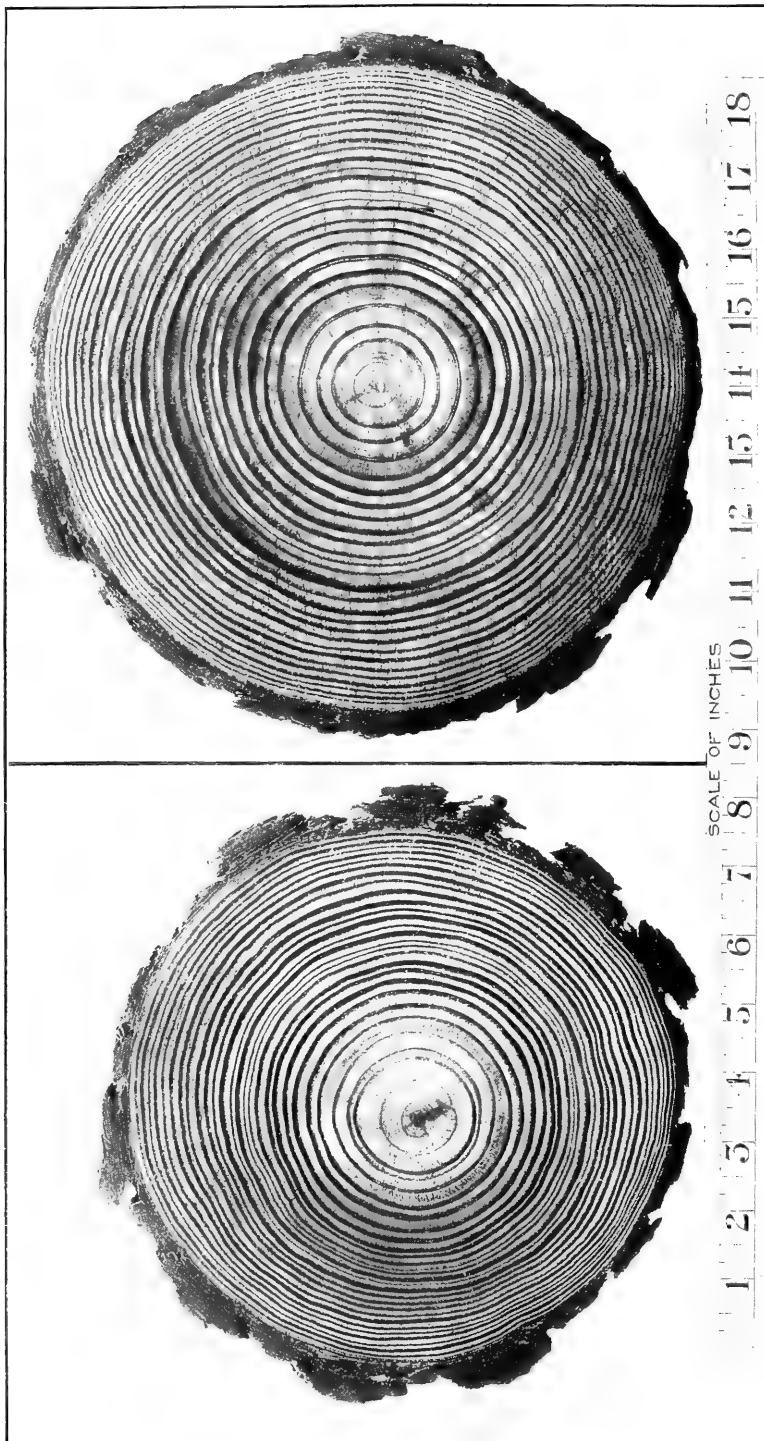
F-13366A

FIG. 1.—A CROWDED 20-YEAR-OLD SHORTLEAF PINE STAND WITH 1,440 TREES PER ACRE, YIELDING A LARGE QUANTITY OF FENCE POLES BUT A SMALL YIELD OF SAW TIMBER.



F-13325A

FIG. 2.—WELL-STOCKED 30-YEAR-OLD SHORTLEAF STAND ON GOOD SITE. TREE DENSITY OF 230 PER ACRE (8 INCHES AND OVER) YIELDED 9,700 FEET OF SAW TIMBER. ARKANSAS NATIONAL FOREST.



F-91746

EFFECT OF TREE DENSITY IN 33-YEAR-OLD SHORTLEAF PINE STANDS UPON GROWTH.

On the left, average tree 9 inches, 550 trees per acre; on the right, tree 10 inches in diameter, 370 trees per acre; less yield but better quality.

INSECTS.

The southern pine beetle¹ (*Dendroctonus frontalis* Zimm.) has been the subject of exhaustive study by Dr. A. D. Hopkins, in West Virginia between 1891 and 1901 and in the Southern States from 1902 to the present time. According to these investigations this insect has caused the death of millions of shortleaf and loblolly trees and some longleaf. The loss during the past 20 years due to this insect has been estimated at between 10 and 20 million dollars. From 1890 to 1893 a serious invasion occurred in Virginia and West Virginia. In the season of 1910 the trouble occurred in many places in the Southern States, leading to a special study and demonstration of methods of control by the Bureau of Entomology and the publication of Farmers' Bulletin 476, from which the recommendations for controlling the insect pest are quoted below because of their value and importance to owners of shortleaf stands. It is important, however, that all of Farmers' Bulletin 476 be consulted in case of extensive or serious infestation.

Evidences of infestation.—(1) If in clumps or patches of pine, where there is no plain evidence of serious injury by fire, the foliage fades to pale green and changes to yellowish and pale brown, it indicates that the trees are dying from the attack of the southern pine beetle, and that the bark of such trees is infested with the developing broods of minute white grubs and transforming beetles; therefore such infested trees are a *menace to the living trees*.

(2) If the trees have reddish brown and partially fallen foliage, or if all of the foliage has fallen, it indicates that the broods of beetles have emerged and that such trees are no longer a menace to the living ones.

(3) If the trees die during the period between the 1st of March and the 1st of October they will be abandoned by the broods of beetles within a few weeks after the foliage begins to fade.

(4) If the trees begin to die during the period between the 1st of October and the 1st of December the broods of beetles will remain in the bark until the following March or April.

Essential details in methods of control.—There are certain essential details in the recommended methods of combating the southern pine beetle which must be observed in order to avoid not only serious mistakes but possibly ultimate failure:

(a) The principal clumps or patches of *dying* trees which are actually infested by the broods of the destructive beetle, as indicated by the *fading and dying* foliage, or otherwise, should be located and marked during the months of November, December, January, and February. In order to do this work, proper experience or special instruction is required. Therefore some one who has had instructions should have charge of the work in each important area in which control work is to be undertaken.

¹ "Report on Investigations to Determine the Cause of Unhealthy Conditions of the Spruce and Pine from 1880-1893," Bulletin 56, West Virginia Agricultural Experiment Station, pp. 281-378, 1899, by A. D. Hopkins, Entomologist.

"The Southern Pine Beetle," Bulletin 83, Part I, Bureau of Entomology, U. S. Department of Agriculture, pp. 56-72, 1909, by A. D. Hopkins.

"The Dying Pine in the Southern States: Cause, Extent, and Remedy," Farmers' Bulletin 476, U. S. Department of Agriculture, 15 pages, 4 figures, 1911, by A. D. Hopkins.

(b) The broods of the beetle in the bark of the main trunks of the medium to larger-sized dying infested trees within an area of 8 or 10 square miles or more must be destroyed in order to stop their depredations.

(c) The broods may be destroyed by one or more of the following methods, the work to be done between the 1st of November and the 1st of March:

(1) Removing and burning the infested bark from the trunks of the standing trees; or

(2) Removing and burning the infested bark from the trunks of the trees after they have been cut down; or

(3) Scorching the infested bark or burning the wood with the bark after the trees are cut down; or

(4) Placing the infested portions of the trunks in water; or

(5) Converting the trunks of the infested trees into cordwood and using the wood for fuel before the beetles leave the bark; or

(6) Converting the infested trees into lumber or other products and burning the slabs or bark.

(d) It is not necessary to burn the tops or branches of treated trees or to cut and burn small infested saplings if the larger infested trees are disposed of.

(e) It is not necessary to remove or destroy the bark on the lower portion of the trunk or on the stumps if it is not infested with the destructive beetle, and it is not necessary to cut or treat dead trees from which the beetles have emerged.

(f) It is necessary and essential that the broods of the destructive beetle in the bark of any portion of the main trunks of the medium to larger sized dying infested trees of any given locality should be destroyed.

(g) If the wood of the infested trees can be utilized for fuel, lumber, or other purposes, its value should cover the cost of the work. If the work of felling and barking the trees is done at direct expense, the cost will average 10 to 30 cents per tree.

(h) The cost of protecting the living timber of any locality with average infestation should not exceed an average of from 1 to 5 cents per acre for the total area of pine-covered land, and if estimated on a basis of volume it should not cost over 2 cents per cord of the living timber protected.

(i) The best time to conduct control operations against the southern pine beetle is during the period between November 1 and March 1.

(j) If a pine tree standing among or near a grove or woods of living pine is either struck by lightning or felled and barked or split into cordwood during the summer and early fall, it will, as a rule, attract the beetles within a radius of 3 or 4 miles and result in the starting of a new center of infestation and in the death of a large number of trees.

(k) The principal owners of pine in each community should cooperate in the disposal of the required infestation, but should not undertake the work until some one or more of the owners is sufficiently familiar with the essential details of the proper methods.

The pine tip moth (*Retinia frustrana* Scud.) attacks and deforms the growing tips of branches. In some localities this is the most noticeable cause of injury and is sometimes very abundant for several successive years. There is no practical means of controlling the insect under forest conditions. The injury is least in suppressed parts of trees, or trees growing beneath older forest stands and greatest in thrifty stands of reproduction from 4 to 10 years old growing in old

fields or under full light exposure. Following the unusually wet spring and early summer of 1912, the infestation was general in the Piedmont region and southern Mississippi Valley. In an extreme case of a 9-year-old stand, as high as 90 per cent of the shortleaf saplings showed injury.¹ Some had been attacked by at least two generations of insects during midsummer, and, as a result, developed two sets of adventitious leaders.

Larvæ of the southern pine sawyer, or round-headed borer, *Monohammus titillator* Fab.,² develop from eggs laid under the bark of felled or dead trees by the adult beetle. The insect never attacks living trees in the South. If allowed to dry rapidly by removing the bark, or if immersed in water, the wood is little subject to injury by the insect.

FUNGI.

The most practical means of combating the injury and loss of timber by fungi is to prevent, so far as possible, the occurrence of wounds in the tree through which the fungus finds its direct avenue of attack. The most serious cause of the formation of wounds is fire. Infested trees should be selected for cutting, since they are the breeding places for spores or "seed," which are minute in size and produced in vast numbers.

YIELD.

The productiveness of the tree, especially of second growth or young timber, being the basis of management, a knowledge of the yield, or amount of wood produced per acre, is essential in order to decide the time and method of cutting, the probability of success, and other important points in handling the forest crop. Yield tables are particularly valuable for trees like shortleaf pine, which come in extensively in even-aged second-growth stands following the removal of the virgin forest and the abandonment of fields cleared for agriculture. For such stands normal yield tables give the information most needed. These are obtained from measurements taken in fully stocked pure stands, or portions of stands, and show the possibilities of the species at various ages. Yield tables thus made are used as guides in ascertaining the present total volume of the growing stock and period of highest productivity in the life of the stand, and in predicting future yields of the forest at given ages. Many stands or portions of stands, however, are not more than two-thirds to three-quarters fully stocked, because of insufficient seed, direct injury from fires, and losses by insects or fungi. A deduction

¹ Mixed stand in which 610 shortleaf and 330 loblolly had been infested and 70 shortleaf and 10 loblolly showed no injury. (Mt. Vernon, Glenville P. O., Arkansas.)

² See Bureau of Entomology Bulletin 58, "Some Insects Injurious to Forests."

must necessarily be made for such stands. The influence of stand density upon yield in saw timber and cordwood is discussed on pages 35 and 36, respectively.

Yields from fully stocked, pure shortleaf stands have been measured in representative regions in the Piedmont uplands of North Carolina, Virginia, and central western Arkansas. In addition, a few yields have been obtained in Georgia, South Carolina, and New Jersey, and are interesting for comparison.

The yield table for the Piedmont region of North Carolina (Table 14) is based upon the measurement of yields of 80 well-stocked stands of various ages up to 80 years. It gives the yields in terms of board feet saw timber, scaled both by the Doyle and the Scribner rules, also cubic feet, for three different qualities of site; also the number of trees per acre, and average height and diameter of the trees. For logs up to 24 inches in diameter the Scribner rule gives higher values, which represent more nearly the actual mill cut than does the Doyle rule. The latter rule is therefore advantageous to the purchaser of standing timber or logs, while it is equally disadvantageous to the seller. For example, at the age of 50 years, on Quality II site, a fully stocked shortleaf pine stand, scaled to include all logs 6 inches and over at the top end, yields an average of 17,000 board feet by the Scribner rule, but only 9,500 feet if scaled by the Doyle rule. The average size of the trees is 57 feet in height by 9.4 inches in diameter, and the stand contains an average of 355 trees per acre, having a total cross section or basal area of 179 square feet at breastheight. The cubic volume, including bark, is 4,360 cubic feet. Table 15 shows that at the age of 50 years, the stand was increasing annually at the rate of 525 board feet per acre, or 106 cubic feet in total stem volume, the average yearly increase during the whole life of the stand (column headed "Mean annual increment") was somewhat less, as might be expected—340 board feet (Scribner), 190 feet (Doyle), or 87 cubic feet per acre.

A similar yield table (Table 16) for fully stocked pure stands of shortleaf in its region of best development west of the Mississippi River is based upon the measurement of 38 sample plots in central western Arkansas. The stands had been protected against frequent fires, and the portions measured were completely stocked, so that the table may be considered as representing fairly well the yields to be expected from protected and managed stands. The number of plots used as a basis for both Tables 16 and 17 is obviously too few, so the tables are tentative, and have been included for the purpose of indicating the character of second-growth stands in Arkansas, with the view of later comparison and revision when additional measurements are available.

TABLE 14.—Yield¹ per acre of fully stocked second-growth shortleaf pine in North Carolina.²

QUALITY I.

Age.	Trees per acre.	Average diameter (breast-high).	Average height.	Total basal area (at breast-height).	Yield of saw timber.		Solid measure.
					Scribner rule.	Doyle rule.	
<i>Years.</i>		<i>Inches.</i>	<i>Feet.</i>	<i>Sq. ft.</i>	<i>Bd. ft.</i>	<i>Bd. ft.</i>	<i>Cu. ft.</i>
20	1,000	5.8	40	158	5,700	2,000	2,120
25	675	6.9	46	175	8,400	3,600	2,730
30	510	7.9	51	188	11,200	5,300	3,350
35	410	8.8	55	198	14,000	7,100	3,950
40	340	9.6	59	205	17,100	8,900	4,570
45	280	10.4	63	211	20,300	10,900	5,200
50	235	11.2	66	215	23,700	12,800	5,840
55	200	11.9	69	218	27,000	14,500	6,450
60	165	12.7	72	220	30,100	16,200	7,020
65	140	13.4	74	222	33,200	17,700	7,570
70	120	14.1	77	224	36,100	19,300	8,100
75	100	14.7	79	226	38,800	20,800	8,600
80	90	15.3	81	227	41,500	22,400	9,110

QUALITY II.

20	1,635	4.6	33	129	3,200	300	1,380
25	1,095	5.6	38	145	5,200	1,700	1,840
30	765	6.5	43	156	7,300	3,200	2,330
35	600	7.3	47	165	9,400	4,700	2,820
40	500	8.0	50	172	11,700	6,300	3,320
45	420	8.7	54	176	14,300	7,900	3,830
50	355	9.4	57	179	17,000	9,500	4,360
55	310	10.0	59	182	19,700	11,000	4,880
60	270	10.6	62	183	22,400	12,500	5,360
65	230	11.3	64	185	25,200	13,900	5,830
70	205	11.8	66	186	27,800	15,300	6,280
75	180	12.4	69	187	30,400	16,700	6,730
80	155	13.0	71	188	32,900	18,100	7,160

QUALITY III.

20	2,450	3.4	26	100	700	-----	650
25	1,880	4.2	31	114	2,100	-----	930
30	1,405	5.0	35	125	3,400	1,100	1,290
35	1,045	5.7	39	133	4,800	2,300	1,670
40	795	6.4	42	138	6,500	3,600	2,070
45	655	7.0	45	142	8,300	4,900	2,470
50	550	7.6	47	144	10,300	6,200	2,880
55	475	8.2	50	145	12,400	7,500	3,300
60	420	8.7	52	146	14,700	8,800	3,700
65	370	9.2	54	147	17,100	10,100	4,100
70	330	9.7	56	148	19,600	11,400	4,490
75	295	10.2	58	149	22,000	12,600	4,860
80	270	10.6	60	149	24,200	13,900	5,230

¹ Based on 80 sample plots in fully stocked stands; total area 21.6 acres. Saw timber scaled to 5.5 inches in top diameter inside bark. Stump height 1 to 1.5 feet. Volume of stem both in board feet and cubic feet, is from 1-foot stump to 6-inch top diameter, including bark. All trees 6 inches and over in diameter breast-high were scaled.

² Counties in North Carolina are: Alexander, Burke, Cabarrus, Catawba, Cleveland, Davie, Gaston, Lincoln, McDowell, Rowan, Rutherford, Surry, Wilkes, and Yadkin.

TABLE 15.—Yearly increment¹ per acre of fully stocked second-growth shortleaf in North Carolina.²

PERIODIC ANNUAL INCREMENT.

Age.	Scribner rule.			Doyle rule.			Solid measure.		
	Quality.			Quality.			Quality.		
	I.	II.	III.	I.	II.	III.	I.	II.	III.
Years.	Bd. ft.	Bd. ft.	Bd. ft.	Bd. ft.	Bd. ft.	Bd. ft.	Cu. ft.	Cu. ft.	Cu. ft.
20	500	370	300	300	280	240	112	82	50
25	530	400	320	320	295	250	117	88	59
30	560	430	340	340	310	260	121	93	66
35	590	460	360	360	315	265	124	98	72
40	620	485	380	380	320	270	126	101	76
45	650	505	400	400	325	275	127	104	80
50	680	525	420	420	330	280	128	106	82
55	655	540	425	365	310	260	123	104	84
60	625	550	455	350	300	260	117	101	83
65	605	560	475	330	290	260	112	97	81
70	580	545	500	315	280	260	106	92	78
75	560	520	475	300	275	255	100	87	75
80	540	490	445	285	265	250	94	82	71

MEAN ANNUAL INCREMENT.

20	285	175	50	100	15	107	69	32
25	335	205	80	140	65	109	74	38
30	370	240	110	175	105	111	78	43
35	405	270	135	205	135	113	81	48
40	430	295	160	225	160	115	83	52
45	450	320	185	245	175	116	85	55
50	470	340	205	255	190	117	87	58
55	490	360	225	265	200	117	88	60
60	500	375	245	270	210	117	89	62
65	510	385	260	275	215	116	90	63
70	515	395	275	275	220	116	90	64
75	520	405	295	280	225	115	90	65
80	520	³ 410	310	280	225	114	90	65

¹ Based on 80 sample plots in fully stocked stands; total area 21.6 acres. Saw timber scaled to 5.5 inches in top diameter inside bark; stump height 1 to 1.5 feet. Volume of stem is from 1-foot stump to 6-inch top diameter, including bark. All trees 6 inches and over in diameter breast high were scaled.

² Counties in North Carolina are: Alexander, Burke, Cabarrus, Catawba, Cleveland, Davie, Gaston, Lincoln, McDowell, Rowan, Rutherford, Surry, Wilkes, and Yadkin.

³ A continuation of these figures indicates a culmination of mean annual increment at about 90 years, with an increment of about 420 board feet.

TABLE 16.—Yield¹ per acre of fully stocked second-growth shortleaf pine in Arkansas.

QUALITY I.

Age.	Trees, total per acre.	Basal area (breast- height), total per acre.	Average diameter trees 6 inches and over.	Height.	Saw timber.		Solid measure.
					Scribner rule.	Doyle rule.	
<i>Years.</i>	<i>Number.</i>	<i>Sq. ft.</i>	<i>Inches.</i>	<i>Feet.</i>	<i>Bd. ft.</i>	<i>Bd. ft.</i>	<i>Cu. ft.</i>
20	639	166	7.5	43	8,000	-----	2,500
25	473	182	8.6	50	12,700	4,200	3,630
30	380	195	9.6	55	17,500	6,600	4,900
35	316	205	10.6	60	22,400	9,700	6,060
40	276	213	11.4	65	27,500	13,400	7,010
45	245	219	12.2	69	32,500	17,600	7,730
50	220	225	13.0	73	37,400	21,800	8,320
55	201	230	13.6	76	42,200	25,600	8,850
60	186	234	14.2	79	46,850	29,000	9,320
65	174	237	14.8	81	51,350	32,100	9,760
70	164	240	15.3	84	55,750	35,000	10,160
75	155	242	15.8	86	-----	37,800	10,520
80	147	243	16.2	88	-----	40,500	10,850

QUALITY II.

20	1,130	125	6.6	35	4,350	-----	1,740
25	784	139	7.5	41	7,450	2,700	2,520
30	595	150	8.3	46	10,600	4,500	3,390
35	479	159	9.1	51	13,800	6,800	4,220
40	404	167	9.9	55	17,000	9,500	4,930
45	351	173	10.7	58	20,200	12,400	5,520
50	308	178	11.3	61	23,450	15,400	6,050
55	277	183	12.0	64	26,850	18,200	6,520
60	249	186	12.5	67	30,600	20,600	6,980
65	229	189	13.1	69	34,050	23,000	7,410
70	214	191	13.6	72	37,500	25,200	7,800
75	197	193	14.1	74	40,850	27,400	8,160
80	184	194	14.5	76	44,000	29,500	8,500

QUALITY III.

20	1,510	-----	-----	-----	-----	-----	-----
25	1,088	95	6.3	33	2,600	1,200	1,390
30	802	105	7.0	37	4,300	2,500	1,870
35	638	113	7.7	41	6,000	3,900	2,360
40	521	120	8.4	44	7,900	5,500	2,850
45	446	126	9.1	47	10,000	7,200	3,310
50	385	131	9.7	50	12,200	9,000	3,760
55	343	135	10.3	53	14,600	10,700	4,210
60	312	138	10.8	55	17,000	12,300	4,650
65	284	140	11.4	57	19,500	13,900	5,070
70	260	142	11.9	59	22,000	15,400	5,450
75	242	143	12.4	61	24,600	16,900	5,810
80	225	143	12.9	63	27,100	18,400	6,150

¹ Based on 38 fully stocked sample plots; area 5.8 acres. All trees 6 inches and over in diameter breast-high were scaled; Top diameter, 5.5 inches; stump height, 1 foot. Table is only preliminary, based upon insufficient measurements but used here for comparison until more complete data are available.

TABLE 17.—Yearly increment¹ per acre of fully stocked second-growth shortleaf pine in Arkansas.

PERIODIC ANNUAL INCREMENT.

Age.	Scribner rule.			Doyle rule.			Solid measure.		
	Quality.			Quality.			Quality.		
	I.	II.	III.	I.	II.	III.	I.	II.	III.
Years.	Bd. ft.	Bd. ft.	Bd. ft.	Bd. ft.	Bd. ft.	Bd. ft.	Cu. ft.	Cu. ft.	Cu. ft.
20	-----	-----	-----	-----	-----	-----	-----	-----	-----
25	940	620	-----	-----	-----	-----	226	156	-----
30	960	630	340	480	360	280	254	174	96
35	980	640	340	620	460	280	232	166	98
40	1,020	640	380	740	540	320	190	142	98
45	1,000	640	420	840	580	340	144	118	92
50	980	650	440	840	600	360	118	106	90
55	960	680	480	760	560	340	106	94	90
60	930	750	480	680	480	320	94	92	88
65	900	690	500	620	480	320	88	86	84
70	880	690	500	580	440	300	80	78	76
75	-----	670	520	560	440	300	72	72	72
80	-----	630	500	540	420	300	66	68	68

MEAN ANNUAL INCREMENT.

20	400	220	-----	-----	-----	-----	125	85	-----
25	510	300	105	170	110	50	145	100	55
30	585	355	145	220	150	85	165	115	60
35	640	395	170	275	195	110	175	120	65
40	690	425	200	335	240	140	175	125	70
45	720	450	220	390	275	160	170	125	75
50	750	470	245	435	310	180	165	120	75
55	765	490	265	465	330	195	160	120	75
60	780	510	285	485	345	205	155	115	80
65	790	525	300	495	355	215	150	115	80
70	795	535	315	500	360	220	145	110	80
75	-----	545	330	505	365	225	140	110	75
80	-----	2 550	340	505	370	230	135	105	75

¹ Based on 38 fully stocked sample plots; total area, 5.8 acres. Saw timber scaled to 5.5 inches in top inside bark. Stump height, 1 foot. All trees 6 inches and over breast-high diameter were scaled.

² A continuation of these figures indicates a culmination of mean annual increment at about 100 years with an increment of about 560 board feet.

ROTATION.

It is always desirable to determine in advance the length of the period through which the stand should be allowed to grow. This depends largely upon (1) the age at which the average yearly growth is greatest, (2) the kind of material desired, pulpwood, cordwood, or saw timber, and (3) the total cost of producing the material. The most reliable basis for determining the age at which to cut the stand is the time when the average yearly production is the greatest. This will then be modified in accordance with the kind of timber that is desired. Other factors to be considered are taxes and protection figured on the basis of compound interest, as well as stumpage values and market demand. The age at which the highest net money return will be secured, or the financial maturity of the stand, may

precede or follow the age of greatest annual growth, depending upon demand and market prices.

Yield and growth tables show the relation between age, size of trees, and total yields. They form the basis, therefore, for deciding when to cut in order to obtain any desired quality and size of timber. For example, on Quality II sites the maximum mean annual yield per acre of saw timber in North Carolina for trees 6 inches and over in diameter (scaled by the Scribner log rule) occurs at about 90 years (Table 15, note), with an average yield of about 420 board feet per year. Fully stocked stands in Arkansas for average Quality II sites appear to reach a culmination of yield of 570 board feet produced annually at the age of about 100 years (Table 17, note). Measurements of similar unthinned stands in Virginia¹ show the culmination of annual yield in saw timber at about 57 years, and those of a few pure stands in New Jersey indicate a maximum annual yield there at 45 to 50 years. The age of culmination in annual volume production is thus increasingly later as the region of growth is better.

The production of cubic volume or cordwood without regard to size or quality appears to culminate about 20 to 30 years earlier than the production of saw timber. The maximum mean annual yield in cubic volume for unthinned well-stocked stands in North Carolina is obtained on the best sites at about 50 to 60 years, on medium or second-quality sites at about 65 to 75 years, and on the poorest or third-quality sites at an estimated age of about 85 years. At 80 years, stands on third quality sites were found not yet to have passed their maximum in volume production. The more rapid growth of thinned stands hastens the date of their financial maturity by from 15 to 30 years.

If the aim is to raise saw timber, a rotation of from 80 years on the better sites to 100 years on the poorer sites will apparently give the greatest yield in the shortest time; for cordwood the age of highest production lies mostly between 60 and 80 years.² In practice stands will more likely be cut in shorter rotations, or before they reach their maximum rate of growth. Pine is extensively cut for ties at 12 inches breasthigh diameter. This size is reached at 65 years in North Carolina, and the tree is then 70 feet high. Such a tree will make two to four ties, according to the size of the tie desired. The disadvantage of holding charges at compound interest tends strongly to reduce the rotation.

¹ W. W. Ashe, "Shortleaf Pine in Virginia" p. 28), published by the Virginia Department of Agriculture and Immigration.

² Scrub and pitch pines are extensively used for firewood and are usually removed from mixed stands with shortleaf because of their inferiority for saw timber.

On the National Forests of Arkansas the Federal Government in its management of shortleaf pine aims to produce the sort of material most needed by the people, which is mostly medium-sized saw timber. A rotation of about 100 years in fully stocked pure stands affords the largest annual yield. The average tree at this age, grown under forest conditions, is 74 feet in height by 16.6 inches in diameter, and contains not less than 270 board feet¹ of merchantable lumber. While the interval between successive cuts is many years, it is well to bear in mind that present cuttings on private holdings in the region are taking very little timber younger than 60 years. Where the stand, whether of pure shortleaf or a mixture of shortleaf and various hardwoods, is moderately open, as is the case over considerable of its range, the culmination in annual yield is earlier. A rotation of 90 years under these conditions will probably give the highest average yearly yield of saw timber on the Arkansas National Forest. Under natural conditions, and without fire protection until very recently, shortleaf pine on the Arkansas National Forest at 90 years measures mostly from 14 to 18 inches in diameter, averaging 15.9 inches, and from 60 to 110 feet in height, averaging 73 feet. The average tree of this size contains 240 feet of saw timber. Judging from the character of similar stands up to 80 years old, pure stands at 90 years on average sites in Arkansas yield from 30 to 40 thousand feet, while completely stocked stands on the same situations contain about 170 trees per acre and yield about 50 thousand feet of saw timber.

THINNINGS.

The extensive areas of shortleaf pine in the younger stages of growth and the quick response of the species to changes in light supply² make thinnings very important in its management; their purpose is to admit the right amount of light so far as is possible to each individual tree. The available soil moisture and growing space for the roots must also be considered. Thinnings are made necessary by the dense seeding which usually takes place under protection from fire, in openings, such as abandoned fields or forest clearings. While natural thinning gradually reduces the density of the stand, progress is slow and much time is lost in the production of a mature crop. Fires thin stands, but in a haphazard manner, accompanied always by severe loss and injury. Thinnings made by selecting the proper trees at the right intervals result in an increased yield, a notable improvement in quality, and frequently a higher net money return on the investment.

¹ Table 29 in Appendix.

² U. S. Department of Agriculture Bulletin No. 244, "Life History of Shortleaf Pine."

RELATION BETWEEN TREE DENSITY AND YIELD.

A thinning is very desirable between the ages of 10 and 15 years. It should be somewhat earlier for the better than for the poorer sites and regions of growth. Subsequent thinnings should be made at regular intervals of 5 years up to the age of from 40 to 60 years, and thereafter about every 10 years to the close of the rotation. If, for any reason, it is impracticable to repeat the operation so often, the interval may be increased to from 7 to 10 years. Ten years is satisfactory for older stands of timber managed under a longer rotation. It is thoroughly practical to start thinnings even at considerably later ages than those mentioned. The limit has not been definitely determined, but vigorous recovery after suppression has been observed up to 80 and 100 years of age. Perhaps ages of 50 to 60 years on the better situations and best regions of growth are approximately near to the average limit of the period of good recovery. This allows a period of 20 to 30 years prior to the culmination of height and diameter growth. On the drier and thinner soils the corresponding upper limit seems to be reached from 10 to 20 years earlier.

Too heavy thinning stimulates leaf development and wood production over the lower branches, correspondingly reduces the rate of height growth, and is injurious also through the exposure of the soil and humus to the unfavorable action of sun and wind. The ideal thinning removes a sufficient number of the trees to relieve overcrowding without creating large openings in the canopy. Obviously, long intervals between thinnings make necessary the removal of a greater amount of material than shorter intervals, and increase the danger of soil exposures and the development of long dense crowns. It should be borne in mind, however, that young stands which are so open as to be considered understocked may often close up as they grow older and be fully stocked at maturity.

The close relation between the number of trees per acre and the resultant yield of saw timber is indicated by Table 18 derived from seven different portions of a 30-year old shortleaf stand of irregular density. The best yield resulted from a density of 350 trees per acre, with decreasing yields at about the same rate from both understocking and overstocking. Thinnings made in Hanover County, Va., for the accurate determination of the resulting growth in a typical shortleaf stand of similar character and age removed 42 per cent of the trees but only 6 per cent of the total cubic volume of wood.

TABLE 18.—*Relation between tree density and yield of shortleaf pine in board feet per acre.*¹

Total trees per acre.	Trees 8 inches and over in diameter.	Saw timber. ²		Average diameter (breast-high).	Total trees per acre.	Trees 8 inches and over in diameter.	Saw timber. ²		Average diameter (breast-high).
		Scribner rule.	Doyle rule.				Scribner rule.	Doyle rule.	
<i>Number.</i>	<i>Number.</i>	<i>Board feet.</i>	<i>Board feet.</i>	<i>Inches.</i>	<i>Number.</i>	<i>Number.</i>	<i>Board feet.</i>	<i>Board feet.</i>	<i>Inches.</i>
150.....	130	11,250	6,600	11.5	500.....	255	15,350	7,900	8.1
200.....	175	13,500	8,450	10.9	550.....	235	13,200	6,800	7.7
250.....	215	16,000	9,700	10.4	600.....	215	11,250	5,800	7.3
300.....	260	18,100	10,600	9.8	650.....	195	9,250	4,450	7.0
350.....	290	19,400	10,800	9.4	700.....	180	7,500	3,200	6.6
400.....	290	19,100	10,200	8.9	750.....	160	5,900	2,000	6.3
450.....	260	17,500	9,000	8.5	800.....	140	4,250	800	6.0

¹ A 30-year old stand of varying densities on good-quality site and protected against fire, Montgomery County, Ark.

² Yield of trees 8 inches and over in diameter at breast-height.

In a selected old-field stand in Arkansas, 20 years old (Pl. VII, fig. 1) a density of 1,440 trees per acre gave a yield of 1,600 board feet, counting all trees 8 inches and over in diameter, while a normal stocking of 520 trees per acre in the same stand yielded 10,200 feet of saw timber. The overstocked stand contained only 40 trees per acre 8 inches and over in diameter and merchantable for saw timber, the well-stocked stands 200. The relation between number of trees per acre and diameter growth is so regular that it is almost susceptible of expression with mathematical exactness. The sections in Plate VIII represent the average growth in a 33-year-old stand of shortleaf pine coming up under full-light exposure in an opening of about 10 square miles caused by a cyclone. A density of 370 trees per acre gave a yield of 18,000 feet of saw timber, a density of 550 trees per acre 21,800 feet. The trees widely spaced averaged 1 inch larger in breast-high diameter, thus yielding a higher grade of lumber.

The number of trees to be left per acre in thinning shortleaf stands of specified ages varies chiefly with the quality of the situation. Table 19 indicates approximately the number of trees in natural unthinned stands and also the trees left after thinning. The better class is representative of the more southern and western portions of the shortleaf range; the poorer class, of unfavorable local situations in this portion of the range, and the more northern and eastern areas of distribution.

TABLE 19.—*Trees per acre in unthinned and thinned stands of various ages.*¹

Age.	Trees per acre.				Age.	Trees per acre.			
	Better situations.		Poorer situations.			Better situations.		Poorer situations.	
	Un-thinned stands.	After thinning.	Un-thinned stands.	After thinning.		Un-thinned stands.	After thinning.	Un-thinned stands.	After thinning.
Years.	Number.	Number.	Number.	Number.	Years.	Number.	Number.	Number.	Number.
20.....	1,400	990	2,120	1,460	70.....	225	195	260	230
30.....	680	525	990	820	80.....	200	175	200	190
40.....	480	380	680	540	90.....	185	165	185	180
50.....	340	280	460	380	100.....	175	160	180	175
60.....	270	230	340	290					

¹ Represents about an average number based on measurements in 128 well-stocked stands in various portions of the range.

TREES TO BE REMOVED.

For convenience in thinning, trees may be divided into four groups of "dominant," "codominant," "intermediate," and "suppressed." These groups are termed "crown classes," and represent the relative importance of the trees in the composition of the stand. The dominant and codominant trees compose the bulk of the stand, forming the general level of the forest canopy. They receive full light from overhead, and the dominant ones some from the sides also. The codominant trees are somewhat crowded on the sides. The intermediate trees have smaller crowns and are generally below the main level of the stand, where they receive only a small amount of light from above. They clearly belong to the class of trees which is being gradually crowded out. The suppressed trees are the smaller sickly ones completely below the general forest canopy.

Although there are certain more or less essential rules for thinning average shortleaf pine stands, they will not fit all cases, and the removal of the trees is largely a matter of individual judgment. In general, thinnings should be made primarily for the better development of the dominant and codominant classes. This is accomplished through the removal of the more crowded intermediate and suppressed trees on the lower side and the exceptionally large, overshadowing or "wolf" trees on the upper side. In the crowded groups it is often necessary to remove as many as one-half, or occasionally two-thirds, of the intermediate trees, together with a few trees of the codominant class. Figure 3 represents an overstocked 30-year-old shortleaf stand and several subsequent thinnings. In ordinary early thinnings the number of trees removed is about one-third of the total stand. The suppressed trees are making exceedingly small growth and exert no appreciable influence upon the stand. Their removal, however, is beneficial in decreasing the fire menace. Large openings should al-

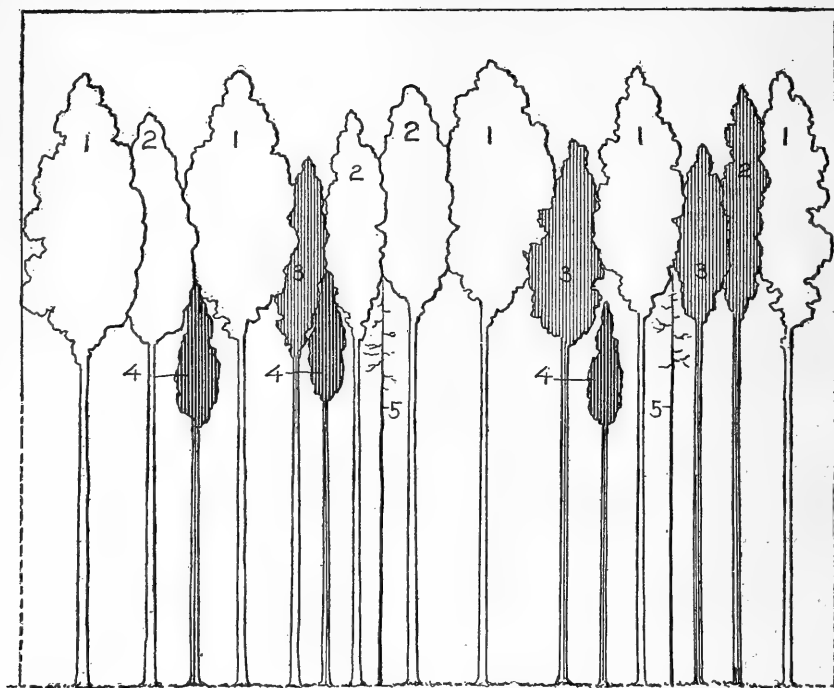


FIG. 3a.—Profile of trees in the original unthinned stand; 15 trees living.

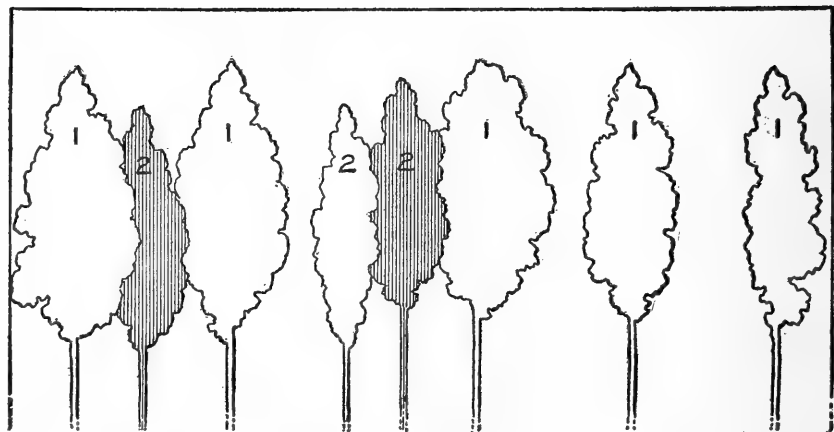


FIG. 3b.—Same stand after first thinning by removing 7 trees; 8 trees living.

FIG. 3.—Successive thinning in an overstocked, even-aged shortleaf stand, 30 years old. 1, dominant; 2, intermediate; 3, suppressed; 4, suppressed; 5, dead. Tree outlines in original stand.

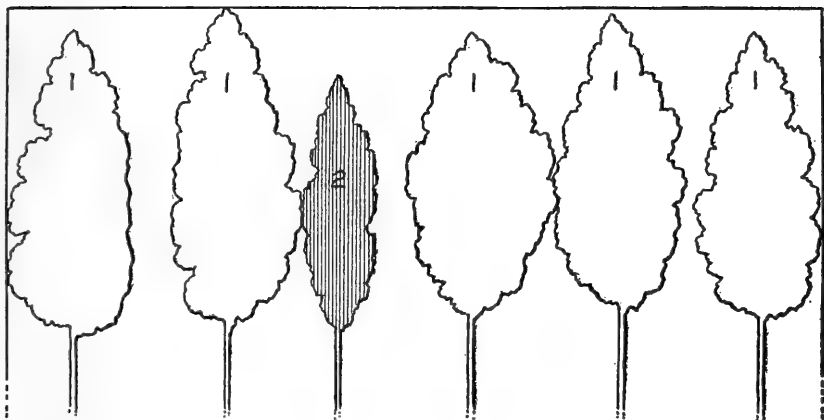


FIG. 3c.—Same stand 7 years later after second thinning; 6 trees living.

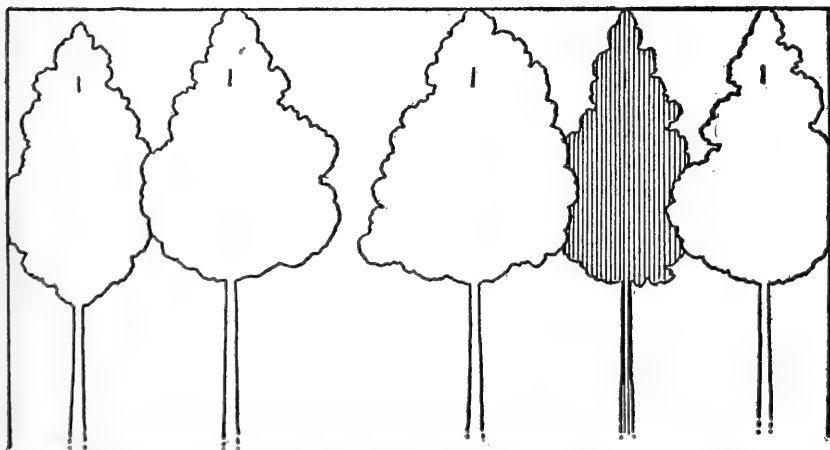


FIG. 3d.—Same stand 8 years later following third thinning; 5 trees living.

Shaded trees to be removed in next thinning. 1, dominant; 2, codominant; 3, inter-taken from "Principles of Handling Woodlands," by H. S. Graves.

ways be avoided in order to prevent soil deterioration and the entrance of weeds or undesirable hardwood species. In the absence of other trees over a space larger than about two or more square rods trees of all crown classes should be retained. The trees in a well-stocked thinned stand of shortleaf should maintain a general uniformity in height.

Figure 4 shows graphically the actual appearance of the canopy of a 30-year-old stand and the same after it was thinned by the removal of 9 suppressed and 4 intermediate trees, equivalent to 46.4 per cent of the number of trees, or about 8 per cent of the cubic volume.

In this case thinning was badly needed because of the number of trees in the lower crown classes and overcrowding in the main

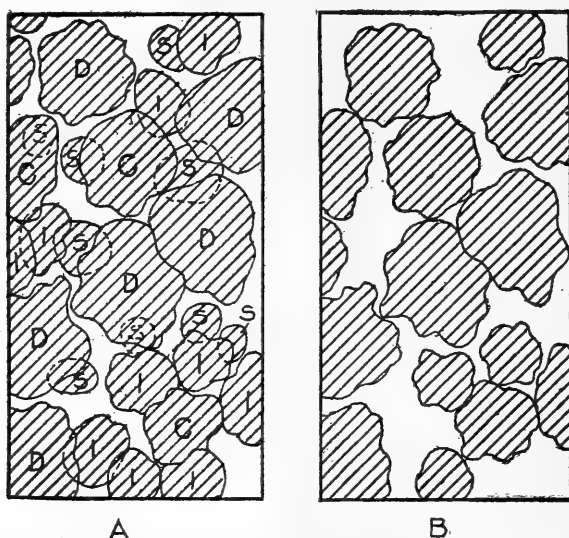


FIG. 4.—Canopy of a crowded shortleaf pine stand 30 years old; (A) before thinning; (B) after thinning. D dominant, C codominant, I intermediate, S suppressed.

canopy. The expansion of the crowns of the remaining trees will rapidly fill openings, making a second thinning necessary in about five years. The selection of trees among the various crown classes for thinning should always be preceded by the removal of unsound and defective trees, such as those with crooked, forked, or short knotty trunks. The presence of "punk," or the fruiting body of a fungus, is certain evidence of a diseased tree.

In mixed stands the pine should be favored at the expense of the hardwoods practically always except on the least favorable situations and extreme outer limits of its range. Artificial thinning will accelerate growth, however, and make the tree successful on situations formerly considered unfavorable. In proportion to the amount of air and soil space occupied shortleaf pine produces more timber

than any of its hardwood associates. In the lower and deeper soils red gum comes close to shortleaf pine in volume production. In general the principles of thinnings stated above for pure stands apply with only minor modifications to mixed pine and hardwood stands.

RETURNS FROM THINNED STANDS.

The relation of cost to financial return is much the same for thinning shortleaf stands as for similar operations with farm crops. The material obtained from thinnings can usually be utilized for cordwood, rails, and other purposes, and often pays for the work from the start. A market for peeled poles can perhaps be developed, especially in view of the success of treating sap pine with wood preservatives. The factors which determine the immediate financial success of thinning an acre of young pine vary widely with age, density, location, and opportunity for using the product.

The results obtained by thinning shortleaf pine in Virginia have been studied by the Forest Service in cooperation with the Department of Agriculture and Immigration of the State of Virginia. The study was made by Mr. W. W. Ashe, of the Forest Service, and the results are embodied in a publication issued in 1913 by the State, entitled "Shortleaf Pine in Virginia—The Increase in Its Yield by Thinnings." The tables and discussion which follow are based upon this report, and may be considered applicable over the northern and central Piedmont region, and with relatively small modifications over the entire region of distribution.

Saw timber.—The largest yield of saw timber is obtained from stands which are periodically and lightly thinned, following an earlier period of moderate crowding. The possibilities of increase in yield of lumber as a direct result of thinning are clearly indicated in Table 20, showing yields for understocked, thinned, and crowded unthinned stands.

TABLE 20.—Yield¹ of saw timber from understocked, crowded, and thinned stands of shortleaf pine in Virginia.

[Trees 9 inches and over in diameter at breast height.]

Age.	Crowded stands, unthinned.		Fully stocked, thinned stands.		Understocked stands.	
	Trees per acre.	Yield.	Trees per acre.	Yield.	Trees per acre.	Yield.
<i>Years.</i>		<i>Bd. ft.</i>		<i>Bd. ft.</i>		<i>Bd. ft.</i>
30	1,235	200	765	8,400	350	3,800
40	860	6,000	505	16,400	300	5,700
50	535	13,100	355	20,400	150	6,900
60	395	16,800	255	23,000	100	7,800

¹ Yield in terms of mill cut production under close utilization.

The yield in saw timber of a crowded stand 30 years old is very small, because very few trees have attained a merchantable diameter. The largest diameters occur in understocked stands, which yield considerably less, however, than fully stocked thinned stands. If the material derived from the thinnings is of sufficient value to pay for the cutting or to yield a profit, the cost per thousand feet of growing saw timber in fully stocked thinned stands is less than in either crowded or understocked stands. If thinnings do not pay for themselves the cost is greater. At the age of about 48 years, when thinned stands reach their maximum annual yield, the diameter of the average-sized tree is about 9.5 inches breast high, or 11.5 inches on the stump. The average annual yield of saw timber at that time from trees 9 inches and over in diameter is 410 board feet. For similar unthinned stands the maximum annual yield occurs at the age of about 57 years, and the tree averages 8.2 inches at breast height, or 9.8 inches on the stump. The annual increment at different ages from unthinned and thinned stands is shown in Table 21.

TABLE 21.—*Average annual increment per acre of saw timber from thinned and unthinned shortleaf-pine stands in Virginia.*

[Trees 9 inches and over in diameter, measured at breast height.]

Age.	Thinned stand (thinnings neglected).		Unthinned stand.	
	Average annual increment.	Periodic annual increment for each decade.	Average annual increment.	Periodic annual increment for each decade.
<i>Years.</i>	<i>Bd. ft.</i>	<i>Bd. ft.</i>	<i>Bd. ft.</i>	<i>Bd. ft.</i>
30	280			
40	410	800	150	
50	408	400	262	710
60	383	260	250	190
70	357	200	238	170

In calculating the cost of growing shortleaf pine saw timber, compound interest on the value of the land, accumulated taxes, and other expenses must be considered. The effect of thinning upon the final yield and upon the cost of growing shortleaf pine are shown in Table 22. The calculation assumes a land value of \$5 per acre, taxes and other expenses at the rate of 1 per cent on the land value, and net annual returns of 5 per cent on the investment in land and cost of stocking. The lowest cost for unthinned stands was \$6.25 and for thinned stands \$2.21 per thousand feet. The age at which the cost is lowest, or the financial maturity of the timber, was 45 years for natural stands and 35 years for the thinned stands.

TABLE 22.—*Cost of growing shortleaf-pine saw timber in thinned and unthinned stands in Virginia.*

Age of stand.	Unthinned stand.			Thinned stand.		
	Accumulated cost of investment.	Yield.	Cost of growing per M.	Net cost per acre of producing crop. ¹	Final yield.	Cost of growing per M board feet.
<i>Years.</i>	<i>Dolls.</i>	<i>Bd.ft.</i>	<i>Dolls.</i>	<i>Dolls.</i>	<i>Bd.ft.</i>	<i>Dolls.</i>
20	11.04	-----	-----	11.04	-----	-----
25	16.46	-----	-----	15.68	900	17.00
30	23.72	200	-----	21.75	8,400	2.59
35	33.43	1,400	23.80	29.64	13,400	2.21
40	46.43	6,000	7.64	40.06	16,400	2.44
45	63.82	10,200	6.25	54.33	18,700	2.90
50	87.10	13,106	6.70	73.70	20,400	3.61

¹ After allowing for profit from thinnings in the form of cordwood.

The total stumpage value of old fields at various ages and the gross returns yielded on the original investment in land are given in Table 23. The investment on which the gross rate of profit is based includes taxes and cost of protection, assumed to be 1 per cent of the land value, here placed at \$5 per acre. The material from the thinnings is assumed to cover the cost of cutting without profit or loss.

TABLE 23.—*Interest yielded and total stumpage value per acre of thinned and unthinned stands of shortleaf pine in Virginia.*

Age of stand.	Thinned stand.			Unthinned stand.		
	Yield per acre.	Value of stand neglecting thinnings. ¹	Gross rate per cent yielded on land value.	Yield per acre.	Value of stand.	Gross rate per cent yielded on land value.
<i>Years.</i>	<i>Bd.ft.</i>	<i>Dollars.</i>	<i>Per cent.</i>	<i>Bd.ft.</i>	<i>Dollars.</i>	<i>Per cent.</i>
30	8,400	16.80	4.3	-----	-----	-----
35	13,400	26.80	5.0	-----	-----	-----
40	16,400	32.80	5.0	6,000	12.00	2.5
45	18,700	37.40	4.5	10,200	20.40	3.2
50	20,400	40.80	4.0	13,100	26.20	3.3

¹ Stumpage at \$2 per thousand feet.

Cordwood.—Since the yield of cordwood from stands of shortleaf pine depends more upon the number than upon the size of the individual trees on a given area, thinnings are not so profitable for cordwood as for saw timber. At the age of 45 years properly thinned stands show an increase in cordwood of 33 per cent, including thinnings; an increase in saw timber of 80 per cent over natural unthinned stands. In each case regular thinnings are made at intervals of five years. Since there is little increase in the actual volume of unthinned stands after the ages of about 35 to 40 years in Virginia, the rotation for cordwood there is relatively short and the maximum yield is reached much earlier than for the production of lumber.

Tables 24, 25, and 26 show the total yield in cordwood, yearly increment, cost of growing, and the stumpage value per acre, and gross rate of money return on the investment for various ages from thinned and unthinned stands.

TABLE 24.—*Cordwood yield per acre of unthinned and thinned pure stands of shortleaf pine in Virginia.*

[Trees 3 inches and over in diameter breast high.]

Age.	Unthinned stands.		Thinned stands—Yield of thinnings.						
	Volume at different ages.	Average increment.	Volume of stand before each thinning.	Number trees which can be removed in each thinning.	Approximate average diameter of trees removed.	Volume of trees removed in each thinning.	Total of all previous thinnings.	Total thinnings and stand. ¹	Average annual increment, including thinnings.
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
<i>Years.</i>	<i>Cords.²</i>	<i>Cords.²</i>	<i>Cords.</i>		<i>Inches.</i>	<i>Cords.</i>	<i>Cords.</i>	<i>Cords.</i>	<i>Cords.</i>
20	47	2.3	47.0	930	3.3	6.1	-----	47.0	2.3
25	57	2.2	52.0	205	4.5	5.1	6.1	58.1	2.3
30	62	2.1	57.0	150	5.0	5.0	11.2	68.2	2.3
35	64	1.9	60.0	110	5.5	4.8	16.2	76.2	2.2
40	65	1.7	60.0	85	6.0	4.3	21.0	81.0	2.0
45	64	1.3	59.0	68	6.5	4.0	25.3	84.3	1.8
50	63	1.2	57.0	55	7.0	3.6	29.3	86.3	1.7
55	61	1.1	54.5	45	7.6	-----	32.9	87.4	1.6

¹ Column 9 is the sum of columns 4 and 8.

² A cord refers to the standard cord of 128 stacked cubic feet, reducible to the long cord by dividing by 1.25. Wood has the bark on and all trees are taken 3 inches and over in diameter.

TABLE 25.—*Cost per cord of growing shortleaf-pine cordwood in unthinned and thinned stands, thinnings included.*

Age.	Unthinned stands.			Thinned stands.					
	Total accumulated cost. ¹	Final yield.	Cost of growing per cord. ²	Thinnings.			Net cost per acre of producing crops. ⁴	Final yield.	Cost of growing per cord. ⁵
				Amount.	Assumed value per cord.	Accumulated value. ³			
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
<i>Years.</i>	<i>Dollars.</i>	<i>Cords.</i>	<i>Dollars.</i>	<i>Cords.</i>	<i>Dollars.</i>	<i>Dollars.</i>	<i>Dollars.</i>	<i>Cords.</i>	<i>Dollars.</i>
20....	11.04	47	0.23	6.1	0.10	-----	11.04	47	0.23
25....	16.46	57	.28	5.1	.15	0.78	15.68	52	.30
30....	23.72	62	.38	5.0	.20	1.97	21.75	57	.38
35....	33.43	64	.52	4.8	.25	3.79	29.64	60	.49
40....	46.43	65	.81	4.3	.25	6.37	40.06	60	.66
45....	63.82	64	.99	4.0	.25	9.50	54.33	59	.92
50....	87.10	63	1.38	-----	-----	13.40	73.70	57	1.30

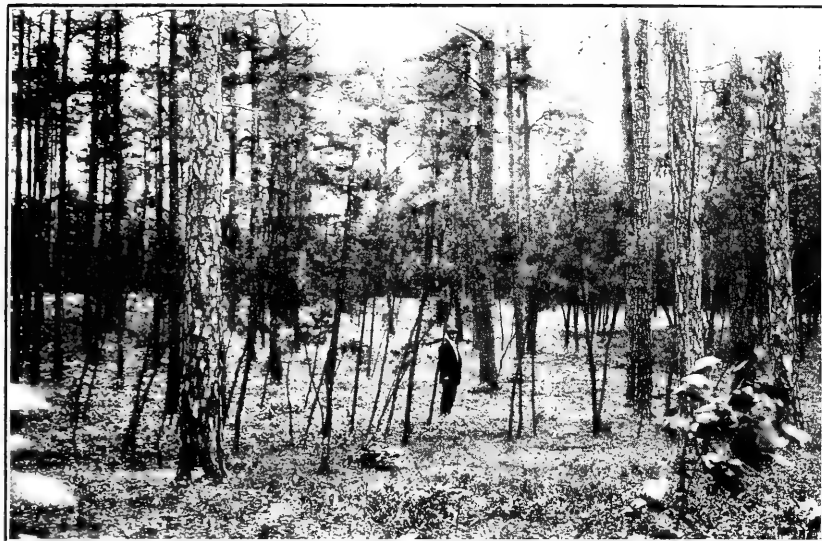
¹ Obtained by calculating the interest at 5 per cent, plus 1 per cent for taxes, making a total of 6 per cent, compounded annually on a land value of \$5 per acre. Since the land will remain after the timber is sold, its value is not included in the cost of growing.

² Obtained by dividing column 2 by column 3.

³ The product of columns 5 and 6 compounded at 5 per cent every 5-year period. The value of wood removed in thinnings (column 6) is only nominal on account of its small size and the difficulty of making thinnings.

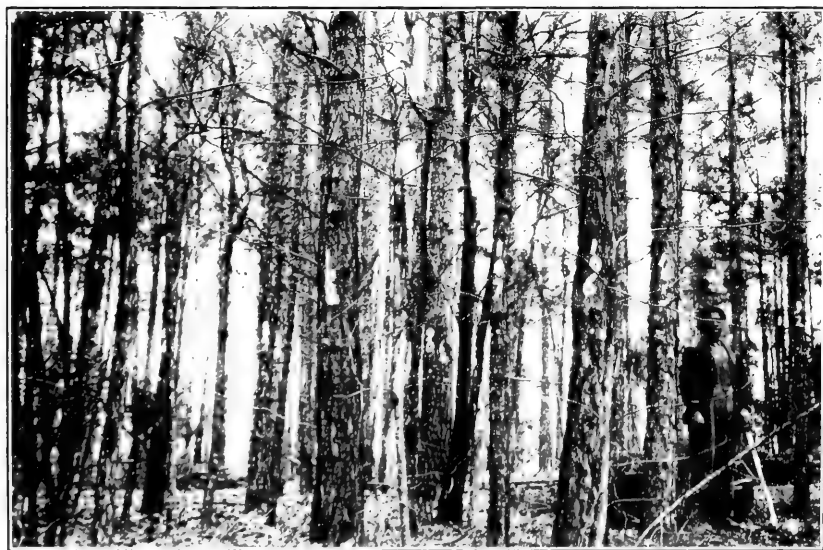
⁴ The remainder after deducting column 7 from column 2.

⁵ Obtained by dividing column 8 by column 9.



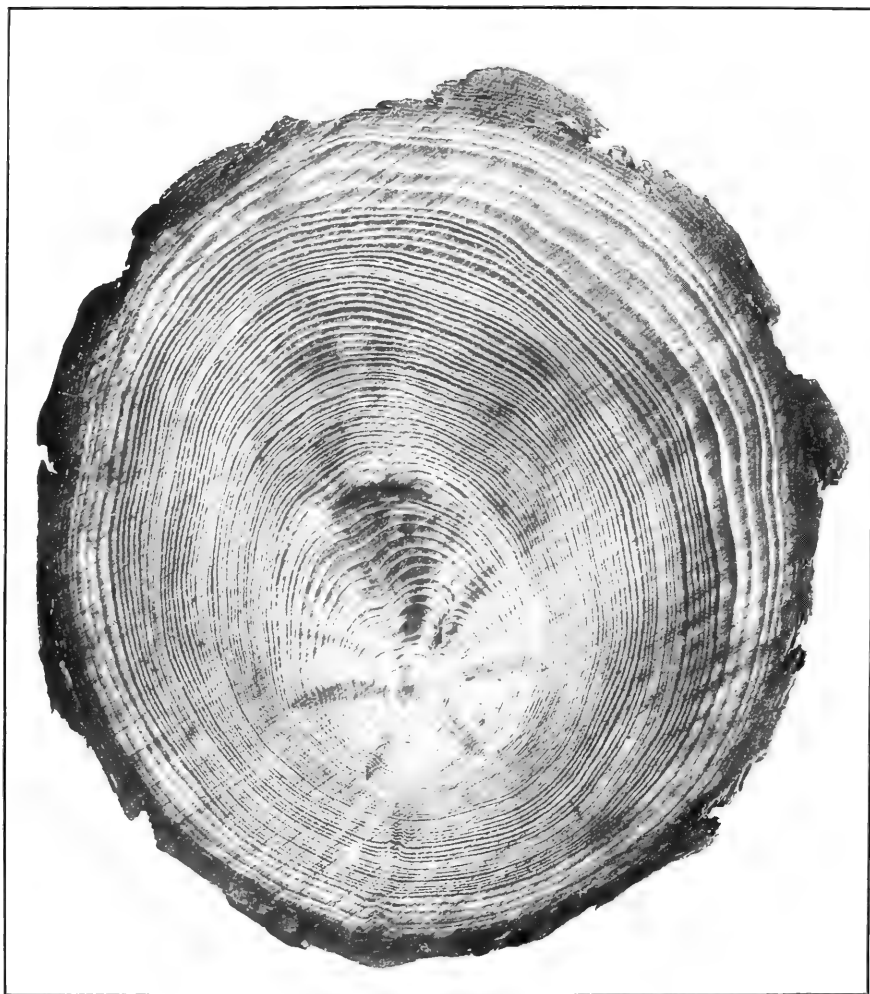
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FIG. 1.—SHORTLEAF REPRODUCTION ENTERING AS SECOND STORY IN OPENINGS IN AN EVEN-AGED STAND IN NEW JERSEY.



F-14208A

FIG. 2.—A 30-YEAR-OLD SHORTLEAF STAND IN VIRGINIA PRIOR TO THINNING.
STANDS OF YOUNG SHORTLEAF PINE.



F-98469

TYPICAL INCREASED GROWTH OF A 66-YEAR-OLD SHORLEAF PINE SINCE LOGGING 5 YEARS AGO. HELLBIG, PIKE COUNTY, ARK. ABOUT 200 PER CENT INCREASE OVER PREVIOUS 5-YEAR PERIOD.

TABLE 26.—*Stumpage value per acre and gross interest yielded on land value from cordwood in old field stands of shortleaf pine in Virginia.*¹

Age.	Thinned stand.			Unthinned stand.		
	Final yield.	Total value per acre including accumulated value of thinnings at 4 per cent compound interest.	Gross rate per cent yielded on land value. ²	Yield per acre.	Value of stand.	Gross rate per cent yielded on land value.
Years.	Cords.	Dolls.	Per cent.	Cords.	Dolls.	Per cent.
20	47	-----	-----	47	11.75	4.3
25	52	13.74	4.0	57	14.25	4.2
30	57	16.08	4.0	62	15.50	3.8
35	60	18.44	3.8	64	16.00	3.5
40	60	19.65	3.6	65	16.25	3.0
45	59	23.94	3.5	64	16.00	2.8
50	57	26.43	3.2	63	15.75	2.5

¹ Cordwood stumpage valued at 25 cents.² Gross interest rate is figured on an investment including cost of protection, and interest on land value assumed to be \$5 per acre. Taxes and other costs equal 1 per cent.

CUTTING AND REPRODUCTION.

In forest management the cutting of stands is looked upon as an intermediate step in the continuous process of timber production. The capacity of the species for natural regeneration usually determines the method of final cut. The easy reproduction of shortleaf pine avoids a loss of time between the timber crops and permits of concentration and economy in lumbering. As the seed is small and matures in abundance about every third year, with partial crops in the interval, it is aggressive and takes complete possession of abandoned fields and clearings. (See Pl. V.)

The essential requirements for the formation of fully stocked young stands are (1) an abundance of light, secured by making large-sized openings, and (2) the presence of seed-bearing trees scattered over or near the openings. The method of cutting depends upon whether the stand is pure or mixed. Shortleaf is most productive in pure stands (Pl. IX).

PURE STANDS.

For pure stands some form of the clear-cutting system should be used. Two methods are suggested. One leaves isolated seed trees scattered uniformly over the tract, and is applicable when the bulk of the contents of the stand is to be taken at one lumbering operation. This system may be modified and applied in the form of a strip, group, or compartment. The other is to clear cut in strips.

The first method scatters seed uniformly and leaves a few trees on the ground for local use after the young growth has been established. This is often a convenience on farms or near small settlements. Trees left for seed should have well-developed crowns and

good root systems so as to be windfirm. Such trees may not occur naturally in the stand. In this case it is advisable to make the last thinning in such a manner as to develop from 4 to 10 good seed trees per acre, well distributed over the area. The number will depend upon the age and size of the trees, more being left on elevations than elsewhere. In the case of long-stemmed, slender trees, groups of two to four serve the purpose better than single trees. At least an average of three of these small groups should be selected for each acre. The crowns of the individual trees or groups as a whole should be entirely freed on all sides by the last thinning. Due allowance should be made for old "forest" or "heart" pine trees that may be left along fence rows or along the margin of a stand. These are usually heavy seed producers. It is essential to mark the good seed-producing trees in advance of logging. Blazing or boxing is injurious and should be strictly avoided. Some simple method, such as the use of strips of old sacking or burlap, is effective and inexpensive. Light hacking in the outer bark only, if done carefully on two sides of the tree, is one method of identifying the trees against cutting. All other merchantable trees may be cut, but if the stand is younger than about 35 years many of the small-sized lower crown classes will recover if left after logging. In most stands there are shade-enduring hardwoods, such as persimmon, sassafras, and dogwood, which have entered small openings in the pine. It is desirable to cut these in order to prevent their developing later and overshadowing the pine saplings.

In unthinned, well-stocked stands good seed trees are not usually developed until the maximum height growth is passed and crown isolation begins to take place, which is at about 40 or 50 years. There are present also many trees of the lower sizes, too small to saw into lumber without a high degree of waste. In such cases the large trees may be logged in a first cutting and the operation repeated after an interval of 5 to 10 years. Groups of seedlings will establish themselves in the successive openings thus left. The remainder of the stand, previously thinned at the time of the second cut, may be removed in a third cutting as soon as a thorough restocking is assured, or they may be held over to form large standards for cutting during the first thinning of the younger stand. In understocked stands a larger per cent of the trees are of a merchantable size and can be taken in the first cut. Seed trees are developed from the smaller trees, which are of less value for saw timber and show rapid development in crown spread and seed production through an increased light supply.

The second method (strip method) leaves alternate strips of clear-cut land and standing timber. The openings may be as wide as four times the average height of the trees and the timber strips one-fourth

the width of the opening. With trees averaging 60 feet in height the relation would be 240 feet of opening to each 60 feet of timber. This would remove four-fifths of the stand and reduce the second cut, or removal of the seed strips, to an operation of small size. If logging costs or market conditions should make such a small cut impracticable the strips should be made of equal width. In case a large tract is being managed to secure a periodic yield, which is sustained, but comparatively small, the strips are cut successively starting from some point or points on the leeward side of the stand. A strip is cut at right angles to the prevailing winds, and another is made to the windward as soon as regeneration is fully secured in the first, and so on. When a strip is being cut, the next one may be thinned by the removal of all the smaller and some of the medium sized trees. This stimulates seed producing within the stand as an aid in restocking the cleared strip. The last remaining strip in the series should be heavily thinned at the time of the preceding cutting and only 15 to 20 of the larger trees left on each acre. These will serve as seed trees, and on account of the rapid crown development following thinning they should fully restock both strips in the course of three to seven years. After this has been accomplished they are removed, as the final cutting of the original stand.

MIXED STANDS.

In mixed stands where shortleaf pine is in competition with various hardwoods it has been found most profitable to encourage the pine, thus bringing about a gradual change in the forest type. Detailed studies carried on by the State in western North Carolina show that this is true in forest management of mixed second-growth oak and pine forests¹ over the Piedmont region from Virginia to Georgia. This is recommended because of the rapid rate of growth and greater general usefulness of the pine timber. Its compact crown and ability to grow with only overhead light enable young shortleaf pine to keep pace with or emerge from the general level of its associates following the coppicing of hardwoods. In brief, the essential steps in accomplishing this desired end are (1) adequate provision for pine seed trees, (2) protection of the young pine in cutting and logging, (3) opening up the forest by the removal of a larger percentage of the hardwoods, and (4) reducing the fire menace. In the mixed stands in the National Forests of western Arkansas and adjacent regions the ranging of hogs in large numbers for many years past has very greatly reduced the natural seeding of the associated nut-bearing oaks and hickories, and by preparing a good seed bed has considerably increased that of shortleaf pine. An advantage is

¹ Bulletin 23, Forest Conditions in Western North Carolina, and Press Bulletins 64 to 84, North Carolina Geologic and Economic Survey.

gained over the hardwoods by cutting them from July to early September, when the sprouting capacity is at its lowest point.

In mixed stands the crowns average larger than in pure stands, with the result of an earlier and larger seed production. The crowns of seed trees should be freed on all sides. Not less than three and usually not more than eight trees, varying with the average seeding capacity, will be needed for each acre. The formation of pure groups on favorable sites, rather than pure stands over larger, variable sites, should be the aim. In some parts of the South scrub pine competes strongly with shortleaf, and on account of its inferior timber should be removed in order to favor shortleaf in seeding up cut-over tracts or abandoned agricultural land.

The selection and clear-cutting methods are alike applicable to mixed and uneven-aged stands. Of these, the selection method is best suited to the prevailing form of mixed stands. The groups of shortleaf pine frequently found among mixed hardwoods are in reality small-sized pure stands and should be handled as such. They are usually even aged, and can be regenerated best by leaving sufficient seed trees to restock the tract completely at an early date. The individual selection of the trees as soon as they have reached the most profitable size is the simplest form of final cutting. This must be modified as required by the dominant aim of increasing the proportion of shortleaf over the less valuable hardwoods. To do this, trees for natural seeding purposes are needed. In many instances much of the shortleaf may profitably be left for the second cutting. It will then have served its purpose of seeding, and a larger amount will be ready for the saw.

CUTTING ON THE NATIONAL FORESTS OF ARKANSAS.

On the two National Forests of Arkansas, where the mixed type prevails, the ultimate aim in the silvicultural management of shortleaf pine is to convert the present more or less uneven-aged forest into even-aged stands. The bulk of the shortleaf pine on these National Forests large enough to cut is from 70 to 175 years old, ranging from over 225 years down to 55 years for trees on the warm slopes. Careful marking of all trees to be cut assures sufficient seed trees. In addition, a minimum diameter limit of 14 inches breast high, equivalent to a stump diameter of 14.9 inches inside bark on a stump 1 foot high, protects the young trees, whose growth and value are increasing at the most rapid rate. It usually provides ample seed trees for restocking and some basis, at least, for a second cut. Growth¹ and volume² tables for western Arkansas show a 14-inch

¹ U. S. Department of Agriculture Bulletin No. 244, "Life History of Shortleaf Pine."

² Table 29, Appendix.

shortleaf pine to be 70 years old, 69 feet high, and to contain 170 feet of saw timber, scaled by the Scribner rule. If left 30 years for a second cut, the 14-inch tree will be 100 years old, 16.5 inches in diameter, 74 feet high, and scale 270 feet by the Scribner rule.

An area of 18 acres on a typical cut-over tract on the Arkansas National Forest cut to a 14-inch diameter limit contained an average of 21.4 shortleaf pines per acre, of which 12.4 were 10 inches and over, breast-high diameter, and yielded 1,497 board feet per acre. The actual cut of pine on the sale area of 800 acres averaged 2,434 board feet per acre, or almost exactly 62.5 per cent of original stand of 4,000 feet. Table 27 shows the size and number of trees left on a sample 18 acres of this sale:

TABLE 27.—*Shortleaf pine left on 18 acres of typical cut-over tract on the Arkansas National Forest.*¹

Diameter (breast- high) in 1910.	Trees.				Diameter (breast- high) in 1940. ²	
	Sample tract. ¹			Total.		Average number per acre.
	1	2	3			
<i>Inches.</i>					<i>Inches.</i>	
5.....	1	-----	8	9	0.5	
6.....	2	4	10	16	.9	
7.....	2	9	20	31	1.7	
8.....	3	14	27	44	2.4	
9.....	14	14	35	63	3.5	
10.....	4	12	24	40	2.2	
11.....	24	14	26	64	3.6	
12.....	16	5	25	46	2.6	
13.....	12	3	13	28	1.6	
14.....	5	2	13	20	1.1	
15.....	3	3	5	11	.6	
16.....	3	3	3	9	.5	
17.....	-----	1	-----	1	.1	
18.....	-----	-----	1	1	.1	
Total.	89	84	210	383	21.4	

DIAMETER AND YIELD IN ABOVE STAND.

Diameter groups.	Trees.		Yield.		Diameter groups (breast- high) in 1940.
	Total (18 acres).	Average per acre.	Total (18 acres).	Average per acre.	
<i>Inches.</i>			<i>Bd. ft.</i>	<i>Bd. ft.</i>	<i>Inches.</i>
4 to 9.....	161	9.0	-----	-----	11 to 13.5
10 to 13.....	178	10.0	20,980	1,166	14 to 16
14 and above.	44	2.4	5,960	331	16.5 up.
Total...	383	21.4	26,940	1,497	-----

¹ Plots selected and measured by H. D. Burrall, January, 1911, in mixed shortleaf and hardwood stand. Three sample plots of 6 acres each. Stand cut to 14-inch diameter limit.

² Based on diameter and growth tables in U. S. Department of Agriculture Bulletin 244, "Life History of Shortleaf Pine."

If a second cut is made in 30 years, the trees now 10 to 14 inches will have reached diameters of 14 and 16.5 inches, respectively. On

this tract there should be at least 10 trees per acre, allowing for a 20 per cent loss in the 30 years. Since shortleaf in forest stands, unless crowded, begins to seed at 30 to 40 years, trees 14 inches and over are at least 3 decades beyond the beginning of seed-bearing age, and probably fully one-third were actual seed producers at the time of the logging. A minimum diameter limit of 14 inches usually provides ample seed trees and a basis of about 10 trees, varying considerably, for a second cut in 30 years. The volume of the 12.4 trees per acre, 10 inches and over in diameter, left on the above cut-over tract, in 30 years will scale 2,675 feet, not counting losses. On the basis, however, of a probable reduction to 10 trees per acre and allowing 20 per cent reduction in scale for defect and breakage, the yield at the end of 30 years will be approximately 2,100 feet or an increase of 40 per cent over the present yield. The factor of accelerated growth, which must be included in the calculation, may safely be counted on to increase the rate at least one-half of the normal, or to a total yield of 2,400 feet. The power of accelerated growth following suppression is definitely known to be retained by shortleaf west of the Mississippi to considerably beyond the age of 70 years. In 7 representative trees, averaging 67 years old (45 to 101 years old), the growth in basal area in the 5 years after logging was 171.4 per cent greater than in the previous 5-year period prior to cutting. (Plate X.) It is believed that the above calculation is conservative.

A 10-inch diameter limit, which represents an average age of 40 years, is about the present minimum commercial diameter limit for the region. If this limit were adopted, it would clearly be necessary in every operation to make special provision for retaining sufficient seed trees. This sort of cutting would result in more uniform conditions on the ground following logging, largely increase the area for incoming reproduction, and thereby gain some ground toward bringing about the desired even-aged form of forest. Wherever the present stand is dominated strongly by pine, in contrast to the mixed pine and hardwoods, and the region is rough or rather inaccessible, it appears that cutting to include the smallest merchantable size will give good results.

The silvicultural principles upon which the marking and logging of shortleaf pine are based are: The high capacity of the species for recovery after suppression, and abundance of seed and demand of the seedlings for light; the possibility, under certain conditions, that shortleaf can profitably be managed on a relatively short rotation; the desirability of growing shortleaf in even-aged pine stands, and at the same time, where necessary, during the first rotation, retaining the younger portion of the stand for a second cut in 30 or more

years. The procedure, in summary, is to (1) protect the vigorous younger growing stock and all pine reproduction against cutting; (2) retain sufficient wind-firm and full-crowned seed trees to provide for completely restocking the area, if possible within the next three years, or natural cycle of full seed production; (3) cut diseased and deformed trees if not needed for seed (leave these for seed only in the absence of better trees); (4) create as full an opening of the forest floor as possible to supply light to the young trees; (5) utilize the hardwoods, favoring white oak over other species because of its greater value; and (6) prevent fires. It is practically certain that shortleaf pine can be profitably extended much more widely within its natural range than it is now by following these suggestions.

REGENERATION BY SOWING AND PLANTING.

Where it can be secured, natural reproduction is of course best, but sometimes it is desirable to start a complete young stand by sowing or planting, especially to fill in blank spaces. The vigor and hardiness of shortleaf pine on well-drained or moderately dry soils make it particularly valuable for reforesting eroded slopes and dry ridges, where, on account of lack of moisture, the growth of hardwoods is retarded. Within its range few other species are so well adapted for reforesting abandoned fields, even those badly gullied, and watersheds supplying water to towns and cities. The work of sowing and planting is especially important because the mature trees which seeded the present old field stands a quarter of a century ago have now become very scarce.

METHODS.

Sowing the seed directly in the field is usually much the cheaper, but transplanting the young trees from nursery beds is the surer method of securing a complete stand.

In direct seeding two methods of preparing the soil are commonly employed. Throwing two or three furrows together reduces the weed competition and prepares a favorable seed bed. Where the surface is rough, steep, or otherwise unfitted for the use of a plow, seed spots are prepared by digging up a space 12 to 18 inches square with a mattock, or, in very loose soil, an ordinary garden hoe. If the soil is loose and reasonably free from weeds, etc., smaller "spots" are sometimes satisfactory. The seeds are then well scattered in the prepared soil and carefully covered. In the plowed furrows seed is sown either in seed spots and covered by using a light mattock or heavy garden hoe or scattered by hand and the strip run over by a brush or spike-toothed harrow. A covering usually of not more than one-quarter of an inch of fine mineral soil is desirable. Too deep covering is unfav-

orable. In dry, loose soil light pressure with the hoe, mattock blade, or shoe sole will aid in checking excessive drying of the surface layer. In order to secure good germination nothing is better than to scatter a half inch or so of fine leaf litter or humus over the surface in addition to the light firming of the mineral soil. A handful of partly decomposed "pine straw" will answer this purpose very well. Early spring is probably the most favorable time for seed sowing, although good results may be expected from fall sowing if the seed is not molested by animals. Fresh seeds will germinate in 15 to 30 days, varying with local climatic conditions.

A spacing of 6 by 6 feet for the seed spots, or 1,210 per acre, is considered about right to provide for a density during early life close enough to stimulate rapid height growth. Regular spacing is not always possible, especially if the tract to be sown contains scattered trees and bushes. A spacing of 8 by 8 feet may be used but does not give quite the desired form development; and closer spacing, for example, 4 by 4 feet, is objectionable, chiefly on account of the additional expense and the need for earlier thinning when the product is insufficient to pay for the labor. Losses of seedlings in considerable numbers because of fungi and animals may be expected during the first one or two years even if protection is afforded. At least 15 to 20 seeds should be sown on each seed spot, allowing for a germination of 40 to 50 per cent for average seed, and the usual destruction of young seedlings during early life. It is desirable that by the end of the germination period each seed spot should contain from five to eight thrifty seedlings. At this rate of sowing and spacing a little over half a pound of seed will be required to sow an acre.¹ Sowing broadcast in plowed furrow strips will usually require a little more seed to obtain the same stand per acre.

Shortleaf pine bears seed abundantly at intervals of from one to three years. The collection of seed is a simple process and not expensive. It is done to best advantage where logging is in progress. The cones are collected from the tops during a period of two to five weeks prior to the time when they would naturally open on the tree. The seed is readily released by applying heat gradually to the cones spread on fine wire mesh, or by exposing them to the drying action of the sun.²

Planting nursery-grown seedlings gives more uniform results than field sowing, but is generally more expensive. The seeds are sown in early spring in prepared and protected beds. Beds 4 by 12 feet

¹ This allows for average well-cleaned seed. If the seed contains much cone scale and leaf litter, allowance should be made accordingly. Clean shortleaf pine seeds average sixty thousand to the pound.

² For additional directions, see Forest Service Circular 208, "Extracting and Cleaning Forest Tree Seed."

are convenient and are extensively used. Sowing is sometimes done in drills spaced 6 inches apart running crosswise in the beds. This permits of cultivation between the rows. Otherwise seed is sown broadcast over the bed and covered by sifting fine sand to a depth of about one-quarter inch. This method better utilizes space in the seedbed and is therefore cheaper. In the latter case about 300 seeds should be sown on each square foot, or a total of one-quarter of a pound of clean seed on each standard seedbed (4 by 12 feet) in order to obtain a final stand of about 5,000 seedlings. This is about 100 per square foot. Sowing at the rate of 50 seed per linear foot in the drills, less than one-tenth of a pound of seed will be required for each seed bed, on which a stand of 2,000 seedlings is desired. These quantities of seed are based upon a germination vigor of 50 to 60 per cent and the probable natural loss of seedlings during the first few weeks.

One-year-old seedlings are inexpensive to raise and handle and give good results when planted out in favorable situations. Two-year-old stock, either seedlings or one year in the transplant bed, give better results on weedy or otherwise unfavorable sites. For the most unfavorable situations 2-year-old transplants are best. To produce these, 1-year-old seedlings with their roots pruned to about 8 inches in length should be transplanted early in the preceding spring into open nursery beds. A spacing of 3 inches in rows 6 inches apart is recommended. Field planting is done preferably in early spring just before root activity starts. Late fall is also a favorable time, and in case of large operations advantage may be taken of both seasons.

FORM OF PLANTATION.

Shortleaf pine is admirably adapted to pure plantations, which are strongly recommended over any kind of mixture in starting young forest stands. Shortleaf may, however, be planted in mixture with heavier foliated species of slower growth—for example, sugar maple and such durable and valuable wood as red juniper. This mixture occurs naturally as a two-storied forest in the Piedmont region. Other species suitable for use in mixture are white, chestnut, red, and black oaks, and hickory. All of these except the close-crowned juniper require much larger growing space and greatly decrease the yield of the pine per acre. In the higher portions of the Piedmont plateau and the southern Appalachian range, white pine and shortleaf in mixture have given good results.¹ The shortleaf, unlike the white pine, prunes itself quickly. The red pine and western yellow pine are not successful in mixture with shortleaf because of the at-

¹ Dr. C. A. Schenck, formerly in charge of the forest on the Biltmore Vanderbilt estate.

tacks of *Aecidium pini*, a rust fungus.¹ Pure plantations of shortleaf promise larger financial returns than any other form. Mixed stands afford better protection against large losses from disease and insect ravages, as well as a variety of wood for use on the farm and to supply markets which may offer better returns for such sales.

Plantations of shortleaf now cover several hundred acres on the Vanderbilt estate at Biltmore in western North Carolina. These were planted beginning about 1900 when this estate was placed under intensive forest management. The average growth in height of the 9-year-old shortleaf pine measured on eight different tracts covering an area of 66 acres was exactly 2 feet annually. The stock used was mostly 1-year-old seedlings, and some 2 years old. Shortleaf has been planted in pure stands and in mixture with sugar maple, white pine, walnut, and other hardwoods. The plantations are strikingly uniform in development and have suffered no serious injury. At 9 years old in mixed plantations sugar maple averages about 7 feet in height, shortleaf pine 18 feet, and white pine mostly from 2 to 5 feet less than the shortleaf.¹ For the upper altitudes of 2,200 to 3,000 feet this mixture was successful, although the pure stands are equally so and are to be preferred. The trees were mostly planted 2 feet apart in rows spaced 5 feet,² and following the contour of the hills in order to check soil erosion. The small 1-year-old seedlings were planted in holes made with a dibble (wooden spike with a handle). Experimental plantations have been made by New Jersey, South Carolina, and possibly other States, but the planting of shortleaf pine on an extensive scale at Biltmore furnishes the best example of the possibility of artificial reforestation.

PROTECTION.

Protection against fire and cattle is essential until the trees are 2 to 4 inches in diameter and the bark is thick enough to prevent injury from these sources. Shortleaf, however, sprouts freely following fire or cutting during the period up to about 10 years of age. In field seeding, mice, chipmunks, and other forms of animal life frequently cause damage during germination. The best means of combating these is to scatter poisoned grain or seed over the tract about a week before and again at the time of seed sowing.³ In more remote regions, where stock laws are antiquated or poorly enforced, it may be necessary to exclude hogs, since they sometimes root up seed spots, although they do not eat the small seeds to any extent.

¹ Dr. C. A. Schenck, formerly in charge of the forest on the Biltmore Vanderbilt estate.

² For average conditions this is much too close a spacing.

³ Formulas for poisoned bait can be obtained upon application to the Bureau of Biological Survey, Washington, D. C.

COST.

The cost of direct seeding varies with the price of labor and size of the operation. From one-half to 1 pound of seed is required for an acre, and one man can sow at the rate of an acre a day. On the basis of \$1.50 for labor and \$2.50 for seed, the cost is not over \$4 per acre. If the soil preparation is by furrow plowing, the item of labor is increased from 50 cents to \$1 per acre. To this must be added the value of the land to get the total initial cost of the investment.

The cost of raising 1-year-old seedlings in lots of 50,000 to 200,000 is about \$2 per thousand, 2-year seedlings about \$2.50, and 2-year-old transplants \$3.50 per thousand. The field labor for planting an acre, spaced 5 by 5 feet, requires one man about two days with the 1-year-old seedlings, or three days with the largest-sized transplants. The total cost of plantations is \$5 to \$8 per acre.

The returns and cost of carrying the investment can be calculated on the basis of the rate of growth, yields at various ages, results from intermittent thinnings, and final cutting, as discussed under the corresponding headings above, the value of the land, the initial cost of establishing plantation, and annual expenses, including taxes and protection, calculated at compound interest.

APPENDIX.

VOLUME TABLES.

Volume tables are usually based on diameter at breastheight and either the total length of the trees or contents of the tree in number of logs of standard length. The contents are most conveniently expressed in cubic feet and board feet of saw timber. It will be noted especially that the contents of the trees scaled by the Doyle rule is very much less than by the Scribner rule. The latter represents much more correctly the actual contents of saw timber in pine stands up to the size of about 24 inches breastheight.

Both volume and taper tables for the Piedmont region are based upon measurements of well-stocked, even-aged second-growth or "old-field" stands in North Carolina taken in 1909, 1910, and 1911. The tables will be found applicable to practically all second-growth shortleaf pine throughout the Piedmont region and lower extension of the Appalachian Plateau. Volume and taper tables for shortleaf pine in Arkansas are based upon the measurements of over 3,000 trees and show the form and average contents of trees of specified diameters in board feet scaled by both the Scribner and the Doyle rules. These tables, although based mostly on measurements taken on the Arkansas National Forest, have been supplemented and found by actual checking to apply in other parts of Arkansas and generally over the southern Mississippi Valley.

TABLE 28.—*Volume in board feet and cubic feet of shortleaf pine of different diameters and heights growing in well-stocked stands in the Piedmont region, North Carolina.*

[Based on taper curves scaled in 16-foot logs, with an additional 8-foot top log in some cases; stump height, 1 foot; diameter inside bark of top, 6 to 8 inches.]

Diameter breast-high.	Total height of tree.								
	40 feet.			50 feet.			60 feet.		
	Scribner rule.	Doyle rule.	Cubic volume.	Scribner rule.	Doyle rule.	Cubic volume.	Scribner rule.	Doyle rule.	Cubic volume.
Inches.	Bd. ft.	Bd. ft.	Cu. ft.	Bd. ft.	Bd. ft.	Cu. ft.	Bd. ft.	Bd. ft.	Cu. ft.
6	1	1	1.2	4	2	1.7	9	3	2.2
7	4	2	3.4	12	4	4.4	20	5	5.3
8	10	5	5.8	20	7	7.3	30	9	8.7
9	18	7	8.2	30	10	10.4	43	14	12.2
10	30	11	10.7	43	16	13.5	57	21	15.9
11	43	18	-----	58	25	16.9	73	33	19.8
12	56	26	-----	73	35	20.0	90	47	24.0
13	-----	-----	-----	89	46	24.0	110	63	28.0
14	-----	-----	-----	106	57	28.0	130	82	33.0
15	-----	-----	-----	-----	-----	-----	150	101	38.0
16	-----	-----	-----	-----	-----	-----	169	122	43.0
17	-----	-----	-----	-----	-----	-----	195	143	48.0
18	-----	-----	-----	-----	-----	-----	220	164	53.0
19	-----	-----	-----	-----	-----	-----	-----	-----	-----
20	-----	-----	-----	-----	-----	-----	-----	-----	-----

TABLE 28.—Volume in board feet and cubic feet of shortleaf pine of different diameters and heights growing in well-stocked stands in the Piedmont region, North Carolina—Continued.

Diameter breast-high.	Total height of tree.									Basis.
	70 feet.			80 feet.			90 feet.			
	Scribner rule.	Doyle rule.	Cubic volume.	Scribner rule.	Doyle rule.	Cubic volume.	Scribner rule.	Doyle rule.	Cubic volume.	
Inches.	Bd. ft.	Bd. ft.	Cu. ft.	Bd. ft.	Bd. ft.	Cu. ft.	Bd. ft.	Bd. ft.	Cu. ft.	Trees.
6	17	4	2.9							11
7	28	7	6.5							15
8	43	12	10.1							28
9	57	18	13.8			15.5				36
10	72	27	17.8			20.0				38
11	90	41	22.0	87	30	25.0				51
12	111	58	27.0	108	49	30.0				57
13	134	78	32.0	134	72	36.0	159	85	35.0	46
14	158	102	38.0	161	97	43.0	192	119	42.0	35
15	186	128	44.0	192	127	50.0	228	157	49.0	24
16	214	156	50.0	225	160	57.0	267	197	56.0	15
17	243	185	56.0	262	196	64.0	310	241	64.0	6
18	275	217	62.0	295	234	72.0	350	285	72.0	4
19	315	249	70.0	334	273	81.0	394	332	81.0	3
20	348	282	77.0	375	313	90.0	438	380	91.0	2
Total.				413	354		482	428	101.0	371

TABLE 29.—Volume in board feet of shortleaf pine of different diameters and heights in Arkansas, scaled by the Scribner and Doyle log rules.

[Based on taper curves; scaled mostly in 16.3-foot logs, with a few shorter logs where necessary; height of stump, 1 foot.]

[illegible]

TABLE 31.—Volume in board feet of shortleaf pine of different diameters and merchantable lengths in 16-foot logs in Arkansas, based on Doyle rule.

[Based on taper curves; scaled mostly in 16.3-foot logs, with a few shorter logs where necessary; height of stump, 1 foot.]

Diameter breast- high.	Number of 16-foot logs.										Diameter inside bark of top.	Basis.
	1½	2	2½	3	3½	4	4½	5	5½	6		
<i>Inches.</i>	<i>Bd.ft.</i>	<i>Bd.ft.</i>	<i>Bd.ft.</i>	<i>Bd.ft.</i>	<i>Bd.ft.</i>	<i>Bd.ft.</i>	<i>Bd.ft.</i>	<i>Bd.ft.</i>	<i>Bd.ft.</i>	<i>Bd.ft.</i>	<i>Inches.</i>	<i>Trees.</i>
8	9	13	17	22	27	33	40	48	57	67	6	3
9	15	21	26	32	38	45	53	62	72	83	6	8
10	21	29	36	44	53	63	74	85	97	110	6	17
11	29	37	47	57	71	85	100	116	134	154	6	49
12	36	47	60	74	89	110	130	152	177	205	7	96
13	44	59	76	93	110	140	160	184	212	243	7	180
14	53	72	93	120	140	170	200	230	264	301	7	367
15		86	110	140	170	200	240	270	310	353	8	389
16		110	140	170	200	240	280	320	370	417	8	401
17		130	160	200	240	280	330	380	430	484	8	345
18		150	190	230	280	330	380	440	490	549	8	342
19			220	270	320	380	440	500	570	640	9	266
20			240	300	360	430	500	570	640	710	9	207
21			270	340	410	480	560	640	730	820	9	164
22			300	380	460	540	630	720	820	920	10	120
23				430	510	600	700	800	910	1,020	10	85
24				470	560	670	780	890	1,010	1,130	10	63
25					620	740	860	980	1,120	1,260	10	34
26					680	800	940	1,080	1,230	1,380	11	21
27					740	880	1,020	1,180	1,350	1,530	11	25
28					800	950	1,100	1,280	1,470	1,680	11	9
29					870	1,020	1,190	1,380	1,600	1,830	11	9
30					930	1,100	1,290	1,500	1,740	2,000	12	2
31						1,180	1,390	1,620	1,880	2,170	12	1
32						1,260	1,490	1,740	2,020	2,340	12	2
33						1,350	1,590	1,870	2,190	2,530	12	1
34						1,430	1,690	2,000	2,340	2,730	13	
Total												3,206

FORM TABLES.

The form or taper of shortleaf trees of different diameters and heights is shown in Tables 32 and 33. The points selected are at breastheight (4.5 feet), and successive intervals above the stump of 8 feet plus 0.15 foot, or 3.6 inches for a 16-foot length, allowed for trimming the log. Table 34, giving the butt taper at various heights up to breastheight for trees of different diameters, will be found useful in correlating stump measurements with the standard tables based upon breastheight diameters. The same is true of the double width of the bark at breastheight for trees of different diameters and heights shown in Table 35.

TABLE 32.—*Diameters inside bark at successive 8-foot intervals¹ of shortleaf pine of different diameters and heights, growing in well-stocked stands in the Piedmont region, North Carolina.*

[Stump height, 1 foot.]

40-FOOT TREES.

Diameter breast- high.	Height above ground.										Basis.
	4.5 feet.	9.15 feet.	17.30 feet.	25.45 feet.	33.60 feet.	41.75 feet.	49.90 feet.	58.05 feet.	66.20 feet.	74.35 feet.	
<i>Inches.</i>	<i>In.</i>	<i>In.</i>	<i>In.</i>	<i>In.</i>	<i>In.</i>	<i>In.</i>	<i>In.</i>	<i>In.</i>	<i>In.</i>	<i>In.</i>	<i>Trees.</i>
4	3.5	3.3	2.7	2.2	1.2	-----	-----	-----	-----	-----	2
5	4.4	4.0	3.3	2.7	1.6	-----	-----	-----	-----	-----	-----
6	5.2	4.7	4.0	3.3	1.8	-----	-----	-----	-----	-----	9
7	5.9	5.4	4.7	3.8	2.1	-----	-----	-----	-----	-----	-----
8	6.7	6.1	5.3	4.3	2.4	-----	-----	-----	-----	-----	2
9	7.5	6.8	6.0	4.9	2.7	-----	-----	-----	-----	-----	-----
10	8.3	7.3	6.6	5.4	3.0	-----	-----	-----	-----	-----	-----
Total...	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	13

50-FOOT TREES.

4	3.4	3.1	2.8	2.6	2.0	1.0	-----	-----	-----	-----	1
5	4.3	3.9	3.6	3.2	2.6	1.5	-----	-----	-----	-----	-----
6	5.2	4.9	4.4	4.0	3.3	2.0	-----	-----	-----	-----	6
7	6.1	5.7	5.2	4.7	4.0	2.4	-----	-----	-----	-----	-----
8	7.0	6.6	6.0	5.4	4.5	2.9	-----	-----	-----	-----	13
9	7.9	7.4	6.7	6.1	5.1	3.3	-----	-----	-----	-----	-----
10	8.8	8.2	7.5	6.8	5.7	3.8	-----	-----	-----	-----	14
11	9.7	9.1	8.3	7.4	6.3	4.3	-----	-----	-----	-----	-----
12	10.7	10.0	9.1	8.1	6.9	4.7	-----	-----	-----	-----	6
13	11.6	10.9	9.9	8.8	7.4	5.1	-----	-----	-----	-----	-----
14	12.5	11.8	10.6	9.4	8.0	5.6	-----	-----	-----	-----	1
Total...	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	41

60-FOOT TREES.

6	5.2	5.0	4.7	4.3	3.9	3.3	2.2	-----	-----	-----	2
7	6.2	5.9	5.5	5.1	4.5	3.8	2.6	-----	-----	-----	-----
8	7.1	6.8	6.3	5.8	5.2	4.4	3.0	-----	-----	-----	21
9	8.0	7.6	7.0	6.5	5.9	4.9	3.3	-----	-----	-----	-----
10	8.9	8.5	7.9	7.2	6.5	5.5	3.7	-----	-----	-----	23
11	9.9	9.4	8.7	8.0	7.2	6.0	4.1	-----	-----	-----	-----
12	10.8	10.3	9.5	8.7	7.8	6.5	4.4	-----	-----	-----	14
13	11.8	11.2	10.3	9.5	8.4	7.0	4.7	-----	-----	-----	-----
14	12.6	12.1	11.2	10.2	9.0	7.6	5.2	-----	-----	-----	8
15	13.5	12.9	11.9	10.8	9.7	8.1	5.5	-----	-----	-----	-----
16	14.5	13.8	12.6	11.5	10.4	8.7	5.9	-----	-----	-----	5
17	15.4	14.6	13.4	12.3	11.0	9.2	6.2	-----	-----	-----	-----
18	16.3	15.4	14.2	12.9	11.6	9.7	6.6	-----	-----	-----	1
Total...	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	74

70-FOOT TREES.

8	7.2	6.9	6.4	5.8	5.5	5.0	4.2	3.0	-----	-----	7
9	8.1	7.8	7.3	6.6	6.2	5.5	4.7	3.3	-----	-----	-----
10	9.1	8.7	8.1	7.3	6.9	6.2	5.2	3.7	-----	-----	36
11	10.0	9.6	8.9	8.1	7.6	6.8	5.7	4.0	-----	-----	-----
12	10.9	10.4	9.7	8.9	8.4	7.4	6.3	4.4	-----	-----	78
13	11.9	11.4	10.6	9.6	9.1	8.1	6.8	4.8	-----	-----	-----
14	12.7	12.2	11.4	10.3	9.8	8.8	7.4	5.2	-----	-----	46
15	13.7	13.1	12.2	11.1	10.5	9.4	7.9	5.5	-----	-----	-----
16	14.5	14.0	13.1	11.9	11.2	10.1	8.5	5.9	-----	-----	18
17	15.4	14.9	13.9	12.6	11.9	10.7	9.1	6.3	-----	-----	-----
18	16.3	15.7	14.6	13.3	12.6	11.4	9.6	6.6	-----	-----	2
19	17.2	16.5	15.4	14.1	13.3	12.0	10.1	7.0	-----	-----	-----
20	18.0	17.2	16.1	14.8	14.0	12.6	10.6	7.3	-----	-----	1
Total...	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	188

¹ Three-tenths foot allowed for trimming on each 16-foot length, or 0.15 foot for each 8-foot length.

TABLE 32.—*Diameters inside bark at successive 8-foot intervals of shortleaf pine of different diameters and heights, growing in well-stocked stands in the Piedmont region, North Carolina—Continued.*

80-FOOT TREES.

Diameter breast-high.	Height above ground.										Basis.
	4.5 feet.	9.15 feet.	17.30 feet.	25.45 feet.	33.60 feet.	41.75 feet.	49.90 feet.	58.05 feet.	66.20 feet.	74.35 feet.	
<i>Inches.</i>	<i>In.</i>	<i>In.</i>	<i>In.</i>	<i>In.</i>	<i>In.</i>	<i>In.</i>	<i>In.</i>	<i>In.</i>	<i>In.</i>	<i>In.</i>	<i>Trees.</i>
10	9.1	8.8	8.3	7.8	7.3	6.7	5.8	4.7	3.1	.....	2
11	10.1	9.7	9.1	8.6	8.1	7.4	6.5	5.3	3.5	.....	.....
12	11.0	10.6	10.0	9.5	8.9	8.2	7.2	5.8	3.9	.....	9
13	11.9	11.5	10.8	10.2	9.7	8.9	7.9	6.5	4.4	.....	.....
14	12.9	12.3	11.6	11.0	10.4	9.7	8.6	7.1	4.9	.....	24
15	13.8	13.3	12.4	11.8	11.3	10.4	9.2	7.7	5.3	.....	.....
16	14.7	14.1	13.3	12.6	12.0	11.1	9.9	8.3	5.8	.....	14
17	15.6	15.0	14.1	13.4	12.7	11.8	10.6	8.9	6.3	.....	.....
18	16.5	15.9	15.0	14.2	13.5	12.5	11.3	9.5	6.8	.....	2
19	17.4	16.8	15.8	15.1	14.2	13.3	12.0	10.1	7.2	.....	.....
20	18.3	17.7	16.7	15.8	15.0	14.0	12.7	10.7	7.6	.....	1
Total...	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	52

90-FOOT TREES.

12	11.0	10.8	10.3	9.8	9.3	8.7	8.0	7.2	6.1	4.5	2
13	12.0	11.7	11.1	10.6	10.1	9.6	8.8	7.8	6.6	4.9	.....
14	12.9	12.6	11.9	11.4	10.9	10.3	9.5	8.5	7.1	5.2	2
15	13.9	13.4	12.8	12.2	11.7	11.0	10.2	9.1	7.6	5.5	.....
16	14.9	14.3	13.6	13.0	12.4	11.8	11.0	9.7	8.1	5.8	2
17	15.7	15.2	14.5	13.9	13.3	12.5	11.7	10.4	8.6	6.2	.....
18	16.7	16.0	15.3	14.6	14.0	13.3	12.4	11.0	9.1	6.5	5
19	17.6	17.0	16.1	15.5	14.8	14.0	13.1	11.7	9.7	6.9	.....
20	18.5	17.9	17.0	16.3	15.6	14.7	13.7	12.3	10.2	7.2	3
Total...	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	14

TABLE 33.—*Diameters inside bark at successive 8-foot intervals¹ of shortleaf pine of different diameters and heights, growing in average stands in Arkansas.*

[Stump height, 1 foot.]

40-FOOT TREES.

Diameter breast-high.	Height above ground.								Basis.
	9.15 feet.	17.3 feet.	25.45 feet.	33.6 feet.	41.75 feet.	49.9 feet.	58.05 feet.	66.2 feet.	
<i>Inches.</i>	<i>Inches.</i>	<i>Inches.</i>	<i>Inches.</i>	<i>Inches.</i>	<i>Inches.</i>	<i>Inches.</i>	<i>Inches.</i>	<i>Inches.</i>	<i>Trees.</i>
6	5.1	4.6	4.1	3.0	.....	.....	.....	.....	.....
7	6.1	5.5	4.9	3.2	.....	.....	.....	.....	.....
8	6.9	6.3	5.5	3.9	.....	.....	.....	.....	.....
9	7.8	7.1	6.4	4.1	.....	.....	.....	.....	.....
10	8.7	8.0	7.0	4.5	.....	.....	.....	.....	1
11	9.6	8.8	7.8	4.9	.....	.....	.....	.....	.....
12	10.4	9.6	8.5	5.4	.....	.....	.....	.....	1
13	11.4	10.5	9.3	5.8	.....	.....	.....	.....	1
14	12.3	11.3	9.9	6.3	.....	.....	.....	.....	.....
15	13.1	12.2	10.7	6.7	.....	.....	.....	.....	.....
16	14.0	13.0	11.4	7.2	.....	.....	.....	.....	.....
Total...	.....	.....	.....	.....	.....	.....	.....	.....	3

¹ Three-tenths foot allowed for trimming on each 16-foot length, or 0.15 foot for each 8-foot length.

TABLE 33.—*Diameters inside bark at successive 8-foot intervals of shortleaf pine of different diameters and heights, growing in average stands in Arkansas—Continued.*

100-FOOT TREES.

Diam-eter breast-high.	Height above ground.														Basis.
	9.15 feet.	17.3 feet.	25.45 feet.	33.6 feet.	41.75 feet.	49.9 feet.	58.05 feet.	66.2 feet.	74.35 feet.	82.5 feet.	90.65 feet.	98.8 feet.	106.95 feet.		
<i>Inches.</i>	<i>In.</i>	<i>In.</i>	<i>In.</i>	<i>In.</i>	<i>In.</i>	<i>In.</i>	<i>In.</i>	<i>In.</i>	<i>In.</i>	<i>In.</i>	<i>In.</i>	<i>In.</i>	<i>In.</i>	<i>Trees.</i>	
10	9.3	8.9	8.6	8.3	7.9	7.4	6.7	6.0	5.1	3.7	2.0				
11	10.1	9.8	9.4	9.0	8.7	8.1	7.4	6.5	5.5	4.1	2.2				
12	11.0	10.6	10.2	9.9	9.4	8.8	8.1	7.1	6.1	4.4	2.4				
13	11.9	11.4	11.0	10.6	10.1	9.5	8.7	7.7	6.6	4.8	2.5				
14	12.7	12.3	11.9	11.4	10.9	10.2	9.3	8.3	7.1	5.2	2.8				
15	13.5	13.1	12.7	12.2	11.6	10.9	9.9	8.8	7.5	5.5	2.9			1	
16	14.3	13.9	13.5	13.0	12.4	11.6	10.6	9.5	8.0	5.9	3.2			3	
17	15.2	14.7	14.3	13.7	13.1	12.3	11.3	10.1	8.5	6.2	3.4			2	
18	16.0	15.6	15.1	14.5	13.8	13.0	12.0	10.7	9.0	6.6	3.5			8	
19	16.9	16.3	15.9	15.3	14.6	13.7	12.6	11.3	9.5	7.0	3.8			24	
20	17.8	17.2	16.7	16.1	15.3	14.3	13.3	11.7	10.0	7.4	4.0			25	
21	18.5	18.0	17.5	16.8	16.0	15.1	14.0	12.5	10.5	7.7	4.3			27	
22	19.4	18.8	18.2	17.6	16.8	15.8	14.7	13.1	11.0	8.2	4.5			33	
23	20.2	19.6	19.1	18.4	17.6	16.6	15.5	13.7	11.5	8.5	4.7			32	
24	21.1	20.5	19.9	19.2	18.3	17.3	16.1	14.3	12.1	9.0	5.0			20	
25	21.9	21.3	20.7	20.0	19.1	18.1	16.9	15.0	12.5	9.4	5.2			10	
26	22.8	22.2	21.5	20.8	20.0	18.9	17.6	15.6	13.2	9.8	5.6			7	
27	23.7	23.0	22.3	21.6	20.7	19.6	18.3	16.3	13.7	10.2	5.8			9	
28	24.6	23.9	23.1	22.3	21.5	20.4	19.1	17.0	14.3	10.7	6.1			4	
29	25.5	24.7	24.0	23.2	22.3	21.1	19.7	17.7	14.8	11.1	6.3			5	
30	26.4	25.6	24.8	24.0	23.1	21.9	20.5	18.4	15.5	11.5	6.6			1	
31	27.4	26.4	25.6	24.8	23.9	22.7	21.2	19.1	16.0	12.0	6.9				
32	28.3	27.4	26.4	25.6	24.7	23.5	22.0	19.9	16.7	12.4	7.2				
33	29.2	28.2	27.2	26.4	25.5	24.3	22.7	20.5	17.3	12.8	7.4				
34	30.1	29.1	28.1	27.2	26.3	25.1	23.5	21.3	18.0	13.3	7.7				
Total	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	211	

110-FOOT TREES.

12	10.9	10.7	10.5	10.1	9.7	9.2	8.6	7.9	7.1	5.8	4.1	2.4		
13	11.8	11.5	11.2	10.9	10.5	9.9	9.3	8.6	7.7	6.3	4.5	2.7		
14	12.7	12.3	12.1	11.7	11.1	10.5	9.9	9.2	8.3	6.8	4.9	2.9		1
15	13.6	13.2	12.8	12.4	11.9	11.4	10.6	9.8	8.7	7.2	5.3	3.1		1
16	14.4	14.0	13.6	13.2	12.6	12.0	11.3	10.5	9.4	7.7	5.7	3.4		4
17	15.3	14.8	14.4	13.9	13.4	12.7	11.9	11.0	9.9	8.2	6.1	3.6		3
18	16.1	15.6	15.2	14.7	14.1	13.5	12.7	11.8	10.6	8.7	6.5	3.9		10
19	17.0	16.5	16.0	15.5	14.9	14.2	13.4	12.3	11.1	9.2	6.8	4.1		4
20	17.8	17.3	16.9	16.3	15.7	15.0	14.2	13.1	11.7	9.7	7.2	4.3		2
21	18.7	18.2	17.7	17.1	16.4	15.7	14.8	13.7	12.3	10.2	7.6	4.6		9
22	19.5	19.1	18.5	17.9	17.2	16.5	15.6	14.5	12.9	10.8	8.0	4.9		5
23	20.5	19.9	19.3	18.7	18.0	17.2	16.3	15.1	13.5	11.4	8.5	5.1		7
24	21.3	20.8	20.2	19.6	18.9	18.1	17.1	15.8	14.2	11.9	8.9	5.4		11
25	22.3	21.7	21.1	20.4	19.7	18.8	17.9	16.5	14.8	12.4	9.3	5.7		6
26	23.1	22.5	21.9	21.3	20.5	19.7	18.6	17.2	15.4	13.0	9.8	5.9		8
27	24.1	23.4	22.8	22.1	21.4	20.5	19.4	17.9	16.1	13.6	10.2	6.2		11
28	24.9	24.3	23.7	23.0	22.2	21.3	20.1	18.6	16.8	14.1	10.6	6.4		2
29	25.9	25.2	24.5	23.8	23.1	22.1	20.9	19.3	17.3	14.7	11.1	6.7		3
30	26.9	26.2	25.4	24.7	23.9	23.0	21.7	20.1	18.0	15.3	11.5	7.0		1
31	27.9	27.0	26.3	25.6	24.8	23.8	22.4	20.8	18.7	15.8	12.0	7.2		
32	28.9	28.0	27.2	26.5	25.7	24.6	23.3	21.5	19.3	16.4	12.5	7.5		1
33	29.8	28.9	28.1	27.4	26.6	25.5	24.0	22.3	20.1	17.1	12.9	7.8		1
34	30.8	29.9	29.0	28.3	27.5	26.3	24.8	23.0	20.8	17.7	13.4	8.1		
Total														90

120-FOOT TREES

12	11.1	10.9	10.5	10.2	9.8	9.3	8.9	8.3	7.6	6.4	5.1	3.7	2.2	
13	12.0	11.6	11.3	10.9	10.5	10.1	9.6	9.1	8.3	7.1	5.6	4.2	2.6	
14	12.8	12.4	12.2	11.8	11.3	10.8	10.3	9.7	9.1	7.8	6.2	4.6	2.8	
15	13.7	13.3	13.0	12.6	12.1	11.6	11.1	10.5	9.6	8.3	6.7	5.0	3.1	
16	14.5	14.2	13.9	13.4	12.9	12.4	11.8	11.2	10.4	9.0	7.3	5.5	3.3	
17	15.4	15.0	14.6	14.1	13.7	13.1	12.6	11.9	11.0	9.6	7.9	5.9	3.5	
18	16.3	15.9	15.5	15.0	14.5	13.9	13.3	12.6	11.8	10.3	8.4	6.3	3.8	
19	17.1	16.7	16.3	15.8	15.3	14.7	14.0	13.4	12.4	10.9	9.0	6.9	4.1	1
20	18.0	17.5	17.1	16.7	16.1	15.5	14.8	14.1	13.2	11.7	9.6	7.3	4.5	2
21	18.9	18.3	17.9	17.4	16.9	16.3	15.6	14.9	13.8	12.2	10.2	7.8	4.7	1
22	19.7	19.3	18.9	18.3	17.7	17.1	16.4	15.5	14.4	12.9	10.8	8.3	5.1	1

TABLE 33.—*Diameters inside bark at successive 8-foot intervals of shortleaf pine of different diameters and heights, growing in average stands in Arkansas—Continued.*

120-FOOT TREES—Continued.

Diameter breast- high.	Height above ground.													
	9.15 feet.	17.3 feet.	25.45 feet.	33.6 feet.	41.75 feet.	49.9 feet.	58.05 feet.	66.2 feet.	74.35 feet.	82.5 feet.	90.65 feet.	98.8 feet.	106.95 feet.	Basis.
<i>Inches.</i>	<i>In.</i>	<i>In.</i>	<i>In.</i>	<i>In.</i>	<i>In.</i>	<i>In.</i>	<i>In.</i>	<i>In.</i>	<i>In.</i>	<i>In.</i>	<i>In.</i>	<i>In.</i>	<i>In.</i>	<i>Trees.</i>
23	20.7	20.2	19.7	19.1	18.5	17.8	17.2	16.3	15.2	13.6	11.4	8.8	5.4	2
24	21.5	21.1	20.6	19.9	19.3	18.7	17.9	17.1	15.9	14.3	12.0	9.2	5.7	2
25	22.5	22.0	21.5	20.9	20.2	19.4	18.7	17.8	16.7	15.0	12.6	9.7	6.1	-----
26	23.4	22.9	22.3	21.7	21.1	20.3	19.5	18.6	17.4	15.7	13.2	10.3	6.4	1
27	24.3	23.8	23.3	22.7	22.0	21.1	20.3	19.3	18.1	16.4	13.8	10.7	6.6	1
28	25.3	24.8	24.3	23.6	22.9	22.1	21.1	20.1	18.9	17.1	14.7	11.3	7.0	2
29	26.3	25.8	25.2	24.6	23.8	22.8	21.9	20.8	19.5	17.8	15.1	11.7	7.2	-----
30	27.3	26.8	26.3	25.7	24.7	23.8	22.8	21.6	20.4	18.6	15.8	12.2	7.6	-----
31	28.3	27.8	27.2	26.6	25.7	24.7	23.5	22.4	21.1	19.3	16.4	12.7	7.8	-----
32	29.3	28.8	28.3	27.7	26.7	25.7	24.5	23.3	22.1	20.1	17.0	13.2	8.1	1
33	30.3	29.8	29.3	28.5	27.6	26.5	25.3	24.1	22.7	20.9	17.6	13.7	8.4	-----
34	31.4	30.9	30.4	29.7	28.6	27.6	26.3	25.0	23.7	21.5	18.2	14.2	8.8	-----
Total														14

TABLE 34.—*Butt taper of shortleaf pine of different diameters in Arkansas.*

Diameter breast-high, outside bark.	Height above ground.				Basis.
	1 foot.	2 feet.	3 feet.	4.5 feet.	
Inches.	Inches. ¹	Inches. ¹	Inches. ¹	Inches. ¹	Trees.
4	4.2	3.8	3.4	3.1	1
5	5.3	4.8	4.4	4.0	-----
6	6.4	5.8	5.4	5.0	3
7	7.4	6.8	6.4	5.9	2
8	8.5	7.8	7.3	6.9	3
9	9.5	8.9	8.4	7.9	8
10	10.6	9.9	9.4	8.9	17
11	11.7	11.0	10.4	9.9	49
12	12.8	12.0	11.5	11.0	96
13	13.8	13.1	12.5	12.0	180
14	14.9	14.2	13.6	13.0	367
15	16.0	15.3	14.7	14.0	389
16	17.1	16.4	15.8	15.0	401
17	18.2	17.4	16.8	16.0	345
18	19.3	18.5	17.9	17.0	342
19	20.4	19.6	18.9	18.0	266
20	21.6	20.7	20.0	19.0	207
21	22.8	21.8	21.0	20.0	164
22	23.9	23.0	22.1	21.0	120
23	25.1	24.1	23.2	22.0	85
24	26.3	25.3	24.2	23.0	63
25	27.5	26.4	25.3	23.9	34
26	28.7	27.5	26.4	24.9	21
27	29.9	28.7	27.5	25.9	25
28	31.1	29.8	28.6	26.9	9
29	32.3	30.9	29.7	27.9	9
30	33.5	32.1	30.8	28.9	2
31	34.7	33.2	31.9	30.0	1
32	35.9	34.4	33.0	31.0	2
33	37.1	35.5	34.2	32.0	1
34	38.4	36.7	35.3	33.0	-----
35	39.6	37.8	36.4	34.0	-----
36	40.9	39.0	37.5	35.1	-----
Total	-----	-----	-----	-----	3,212

¹ Diameter inside bark.

TABLE 35.—*Bark width at breastheight of shortleaf pine of different diameters and heights in Arkansas.*

Diameter breast- high.	Height of tree.									Basis.
	40 feet.	50 feet.	60 feet.	70 feet.	80 feet.	90 feet.	100 feet.	110 feet.	120 feet.	
<i>Inches.</i>	<i>Inches.</i> ¹	<i>Inches.</i> ¹	<i>Inches.</i> ¹	<i>Inches.</i> ¹	<i>Inches.</i> ¹	<i>Inches.</i> ¹	<i>Inches.</i> ¹	<i>Inches.</i> ¹	<i>Inches.</i> ¹	<i>Trees.</i>
8	.85	.75	.64	.50	.....	.....	.....	.....	.....	2
9	.92	.82	.71	.59	.....	.....	.....	.....	.....	2
10	.98	.88	.78	.67	.....	.....	.....	.....	.....	10
11	1.04	.94	.85	.75	.....	.....	.....	.....	.....	16
12	1.10	1.00	.91	.81	.74	.....	.....	.....	.....	47
13	1.15	1.06	.97	.87	.80	.....	.....	.....	.....	34
14	1.20	1.11	1.02	.93	.85	.78	.....	.....	.....	49
15	1.25	1.16	1.06	.97	.90	.83	.....	.....	.....	44
16	1.29	1.20	1.10	1.01	.94	.87	.....	.....	.....	53
17	.....	1.25	1.14	1.05	.98	.91	.85	.....	.....	48
18	.....	1.29	1.18	1.08	1.01	.94	.88	.83	.....	44
19	.....	.....	1.21	1.11	1.04	.97	.91	.86	.....	113
20	.....	.....	1.24	1.13	1.06	.99	.94	.88	.....	74
21	.....	.....	1.27	1.16	1.09	1.01	.96	.90	.80	56
22	.....	.....	1.30	1.18	1.11	1.03	.98	.92	.82	36
23	.....	.....	1.33	1.20	1.12	1.05	1.00	.94	.84	47
24	.....	.....	.....	1.22	1.14	1.06	1.01	.95	.86	31
25	.....	.....	.....	1.23	1.15	1.07	1.02	.96	.87	32
26	.....	.....	.....	.....	1.17	1.09	1.03	.97	.89	21
27	.....	.....	.....	.....	1.18	1.09	1.04	.98	.90	25
28	.....	.....	.....	.....	1.19	1.10	1.05	.99	.91	9
29	.....	.....	.....	.....	1.19	1.11	1.06	.99	.92	9
30	.....	.....	.....	.....	1.20	1.12	1.06	1.00	.92	2
31	.....	.....	.....	.....	1.21	1.12	1.06	1.00	.93	1
32						1.13	1.07	1.00	.93	2
33						1.14	1.07	1.00	.94	1
Total.										808

¹ Double width of bark at breastheight.

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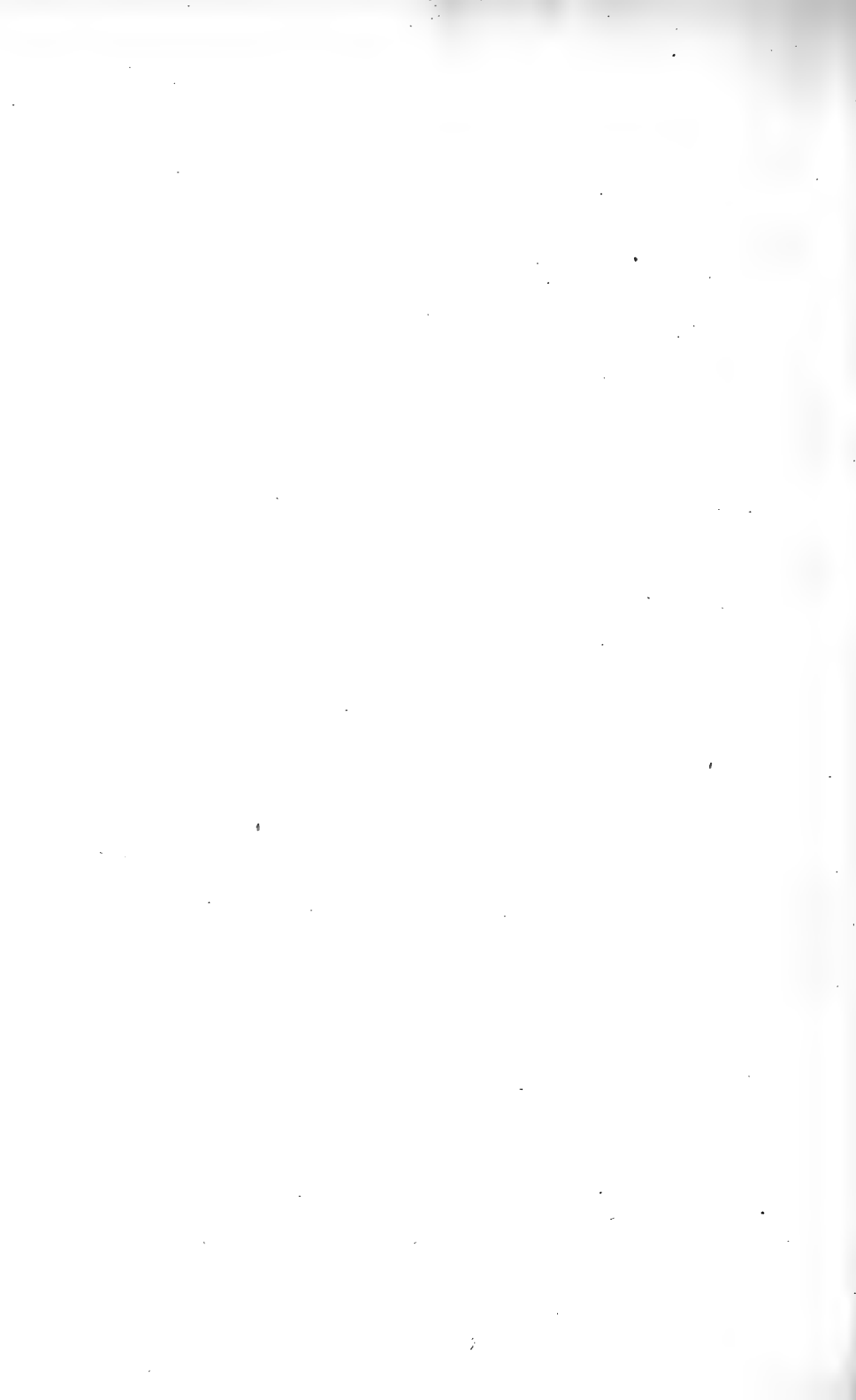
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UNITED STATES DEPARTMENT OF AGRICULTURE



BULLETIN No. 309



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WM. A. TAYLOR, Chief

Washington, D. C.

PROFESSIONAL PAPER

November 4, 1915

ZACATON AS A PAPER-MAKING MATERIAL.

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This bulletin is printed upon paper derived from the zacaton plant.

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INTRODUCTION.

There appears to be a constant and increasing interest in the discovery of plant materials which may be substituted for wood and rags in the making of paper stock of various kinds. The uses to which paper may be put are multiplying rapidly, the consumption for present purposes is increasing greatly, and there is a constant depletion of existing supplies. Many materials from both wild and cultivated plants are at present going to waste, so that a natural desire to save them adds to the general interest in the subject. This interest is world wide and practically spontaneous. In southern China bamboos and rice straw are under experiment; in Manchuria the stalks of the grain sorghums; in Mexico wood waste and various trees not now used for other purposes; and in Egypt the plant formation known as Nile suud, which constitutes the dense jungle growth of the upper White Nile and contains a large proportion of papyrus plants. In the Philippines attention is being given to bamboos and various other grasses and also to the fibrous by-products of the Manila-hemp indus-

¹ The Paper-Plant Investigations of the Bureau of Plant Industry are conducted under the direction of Charles J. Brand, Chief of the Office of Markets and Rural Organization.

NOTE.—This bulletin should be useful to all persons who are interested in the economic phases of paper making, especially to print and book paper manufacturers. It has a botanic and chemical interest as well.

try. In this country scarcely a month passes during which some new wild plant or crop waste is not proposed as a certain and permanent relief to the paper manufacturer from the stress resulting from the rising cost of raw materials.

The past 10 years have witnessed an enormous growth in the pulp and paper industry and a keener realization of the fact that the present wood supply of the United States can not indefinitely withstand the demands placed upon it. About 80 per cent of the paper stock used in this country is derived from wood. In 1900 about 2,000,000 cords of wood were used for pulp manufacture, and the present use is approximately 4,500,000 cords a year. Pulp-wood imports in this country increased from 650,000 cords at \$4.20 per cord in 1907 to 1,036,000 cords at \$6.60 in 1913. In 1903, 131,000 tons of wood pulp were imported, as against 563,000 tons in 1913.

In a report of the United States Forest Service in 1914 the annual growth of wood in the United States is placed at 12 cubic feet per acre per year, while there are being removed 36 cubic feet per acre per year; in other words, as a nation, wood is being used three times as fast as it grows. Without doubt imported wood will play an important rôle in the paper industry of this country for many years to come.

New woods are in common use to-day which would not have been considered a few years ago, and reforestation is being given very serious attention, all of which goes to show a desire on the part of the pulp manufacturer to husband his present source of supply or to secure new sources.

Since the demand for paper stock is gaining so rapidly upon the supply it is very clear that the price of raw material will continue to increase and in so doing will bring other raw materials into competition. It is for this reason that investigations of the adaptability of fibrous plants and crop wastes should be carried on with some of the more promising materials.

The Office of Paper-Plant Investigations of the Bureau of Plant Industry has numerous materials under examination and proposes from time to time, as the data obtained may warrant, to publish the information which has been secured. The publication of these data will not mean that the work with the material has been completed or that the conclusions reached are final. There is always a possibility that further information and the devising of new and better methods may result in taking a raw material from the class of unpromising materials and placing it in the class of promising materials.

The work with zacaton (*Epicampes macroura* Benth.) has progressed to a point where at least a preliminary publication of results is desirable.

BOTANICAL HISTORY AND SYSTEMATIC POSITION OF ZACATON.

The genus *Epicampes* was established by Dr. J. S. Presl, of the University of Prague, in his treatment of the Gramineæ in 1830.¹ The type species of the genus is *Epicampes strictus*, which Presl figures on plate 39 of his work.

The following characterization of the genus is taken from Scribner:²

Epicampes Presl, Rel. Haenk. 1:235, t. 39. 1830. Spikelets small, 1-flowered. Empty glumes 2, membranaceous, slightly unequal, convex on the back, carinate, often finely 3-nerved; flowering glumes 3-nerved, obtuse or emarginate, a little shorter or about the length of the empty glumes, and tipped with a slender, usually rather short awn, which is rarely wanting. Stamens 3. Styles distinct, short; stigmas plumose. Grain included within the glumes, free. Tall, perennial grasses with usually very long, spikelike, many-flowered panicles.

The genus belongs to the tribe Agrostideæ of Engler and Prantl,³ to which the true esparto, *Stipa tenacissima* L., also belongs. This grass is extensively used for paper making in the Old World, the raw material coming chiefly from Spain, Algeria, and Tripoli. The species *Epicampes macroura*⁴ has received several common names, most of which refer to the utilization of its roots in the manufacture of brushes. Broom-root grass, wire-grass, and rice-root grass are the common English names. Rice, in this case, has no relation to the well-known rice grain of commerce, but the name arises from the

¹ Presl, K. B. Reliquiæ Haenkeanae . . . v. 1, p. 235, pl. 39. Pragae, 1830.

² Scribner, F. L. American grasses—III. U. S. Dept. Agr., Div. Agros. Bul. 20, p. 75, 1900.

³ Hæckel, Ernst. Gramineæ (echte Gräser). In Engler, Adolf, and Prantl, K. A. E. Die Natürlichen Pflanzenfamilien . . . T. 2, Abt. 2, p. 45, 50. Leipzig, 1887.

⁴ This grass was first brought to the senior writer's attention in December, 1909, by Mr. L. H. Dewey, Botanist in Charge of Fiber Investigations, who transmitted a bundle of the grass tops for possible test. The sample weighed between 2 and 3 pounds and had been sent to Mr. Dewey from Mexico by the Ox Fiber Brush Co., of Frederick, Md. Subsequently, Mr. O. F. Cook, Bionomist in Charge of Crop Acclimatization and Adaptation Investigations, directed the writer's attention to certain notes of his on *Epicampes* previously published. (Cook, O. F. Vegetation affected by agriculture in Central America. U. S. Dept. Agr., Bur. Plant Indus. Bul. 145, p. 19-20, 1909.) These notes are of sufficient interest, showing the size, resistance, and aggressiveness of the grass, to warrant quoting them in this connection. Discussing the distribution of pines and oaks as determined by the clearing of land, Mr. Cook says:

"Ability to resist fire is the characteristic that enables the pines to establish themselves in open grass lands. Young pines with the growing bud surrounded by many green needles can survive fires that kill seedlings of other plants. As the trees grow larger they are protected by a thickened bark which is a very poor conductor of heat and not readily combustible. Nevertheless, the survival of the pines depends on the chance of frequent fires which prevent the accumulation of grass in large quantities. With grass enough to burn, even large pines may be killed by fire and the pine forest driven back from areas it has already occupied. In this way a species of wire-grass (*Epicampes*) is destroying forests of alders and pines on the upper slopes of the Vulcan de Agua in Guatemala. Before the access of fires this grass appears to have been confined to the crater and to the very dry upper slopes, where the pine trees are small and scattering. Now that the belts of humid forests lower down have been broken by clearings the grass has the assistance of fire and is destroying the trees with increasing rapidity.

"There are no springs or streams on the upper slopes of the volcano, so that the grass is not pastured. Its long wiry stems and leaves accumulate until there are quantities of fuel sufficient to kill large trees and to drive back the forest for long distances at each conflagration. The lower the grass comes the more luxuriant its growth and the more destructive the next fire. This will continue as long as the grass is ungrazed or care is not taken to burn the grass every year in order to prevent the accumulation of dangerous quantities of fuel.

"The roots of this grass are well protected from the fire by masses of the closely packed stems. These tufts remain wet while everything else is thoroughly dried. Except in rainy weather, no water can be obtained from the extremely coarse and loose volcanic ashes and rocks of which the upper parts of the mountain are composed."

fact that the Mexican name for the roots is "Raiz de zacaton"; that is, roots of grass, in literal translation. Zacaton¹ is the name most commonly applied to the species in Mexico. The French name for

the root-brush material is "chiendent," while "Mexican whisk" is still another name applied to it.

The first known collection of *Epicampes macroura* was made by Humboldt and Bonpland in the mountains of Toluca, in the State of Mexico, at an altitude of 10,500 feet, sometime prior to 1815. In the working up of this collection the specimens were assigned to the genus *Crypsis* Ait. under the specific names *macroura*, *phleoides*, and *stricta*. About 1829, when Kunth published that portion of his "Révision des Graminées"² containing the Agrostideæ, he evidently had changed his mind as to the assignment of these specimens to *Crypsis* and reassigned them

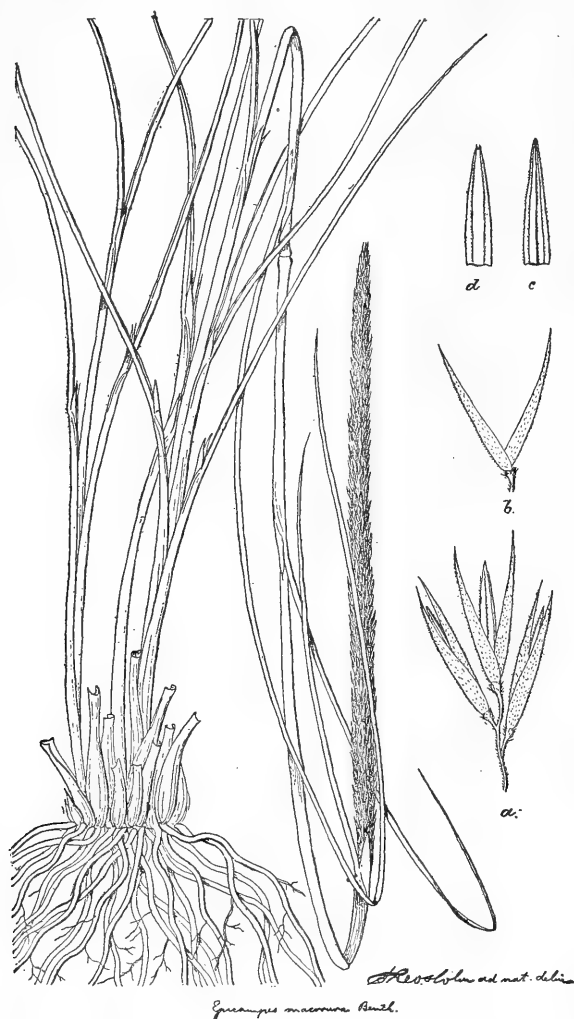


FIG. 1.—Zacaton (*Epicampes macroura*), whole plant, one-sixth natural size. *a*, Three spikelets, 4 times natural size; *b*, empty glumes, 4 times natural size; *c*, flowering glume, dorsal view, 4 times natural size; *d*, palea, dorsal view, 4 times natural size.

to Linnæus's genus *Cinna*. Many years later, about 1886, Eugène Fournier,³ in working up the collections of Mexican plants deposited in the herbarium of the Museum of Paris, established a new genus,

¹ Zacaton as a common name is applied also to *Muhlenbergia distichophylla* (Presl) Kunth and *Sporobolus wrightii* Munro.

² Kunth, K. S. Révision des Graminées. 3 v. Paris, 1829.

³ Fournier, Eugène. Mexicanas Plantas . . . pars. 2, p. 90. Parisiis, 1886.

which he called *Crypsinna*, based in part on the *Crypsis* of Humboldt, Bonpland, and Kunth,¹ and in part on the *Cinna* of Kunth. As established by Fournier, *Crypsinna* included the species *stricta*, *macroura*, and *setifolia*. In November, 1881, Bentham,² having seen a proof or a copy of Fournier's work before its publication, disagreed with him and assigned the species *macroura* and *stricta* both to *macroura* in the genus *Epicampes* Presl.

The following characterization of *Epicampes macroura* has been translated from the original Latin description by Humboldt, Bonpland, and Kunth:¹

Crypsis macroura. Culm erect, simple, glabrous; leaves and sheaths scabrous; panicle spikelike, very long, cylindrical, erect; glumes equal, [flore]t nearly as long as the glumes. Found on the sunny side of a mountain in the State of Mexico near the mountain of Toluca, at an altitude of 11,000 feet. Flowers in September.

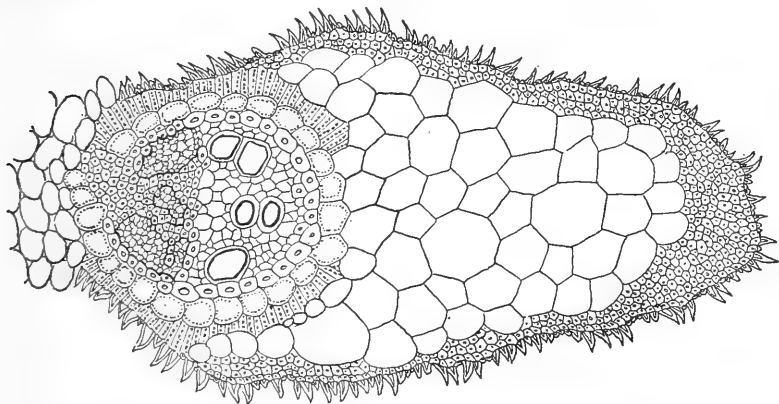


FIG. 2.—Cross section of part of a culm from the epidermis to the central cavity, $\times 320$, showing hypodermal stereome, two mestome strands, and colorless parenchyma between them.

Culms erect, simple, 3 or 4 feet tall, glabrous, pubescent below the glabrous nodes. Leaves narrowly linear, convolute (?), striate, slightly scabrous. Sheaths rather lax, striate, glabrous, longer than the internodes. Ligule very long, less than 1 inch, bifid (2-cleft), glabrous, the lobes acuminate. Panicle spikelike, dense, cylindrical, strictly erect, 1 foot long. Spikelets pediceled, the pedicels scabrous. Glumes linear, acuminate, carinate, subequal, nearly glabrous, ciliate-hispid on the back, green. Florets slightly shorter than the glumes, lanceolate, acute, the lemma and palea concave, equal, slightly scabrous, green; the lemma 3-nerved, the palea 2-nerved, narrower.

The general appearance of a few culms taken from the tufts in which this grass usually grows is shown in figure 1, which was drawn from a herbarium specimen. Figures 2 to 6, inclusive, show the microscopical structure of the zacaton plant.³ The appearance of an average and two small-sized tufts is shown in figure 7. These

¹ Humboldt, Alexander, Bonpland, A. J. A., and Kunth, K. S. *Nova Genera et Species Plantarum*. . . t. 1, p. 140-141. Lutetiae Parisiorum, 1815.

² Bentham, George. *Notes on Gramineae*. In *Jour. Linn. Soc.* [London], Bot., v. 19, p. 87-88. 1881.

³ The drawings for figures 1, 2, 3, 4, 5, 6, and 11 were made by Dr. Theodor Holm.

tufts furnished the raw material for the first laboratory experiments with zacaton.

DISTRIBUTION OF ZACATON.¹

The genus *Epicampes* is exclusively American. About 16 species have been described, some of which, in the opinion of expert agrostologists, would not retain specific rank under critical study. The ranges of the various species extend from California and Texas southward to the Argentinian Andes. Mexico is richest in number of species, and there also the root-harvesting industry has reached its highest development. *E. macroura* has been reported from many widely separated localities from Texas to Central America. The collection in the United States National Herbarium embraces specimens from the following localities in Mexico: Canyon de San Diego, State of Chihuahua; San Luis Potosi, State of San Luis Potosi;

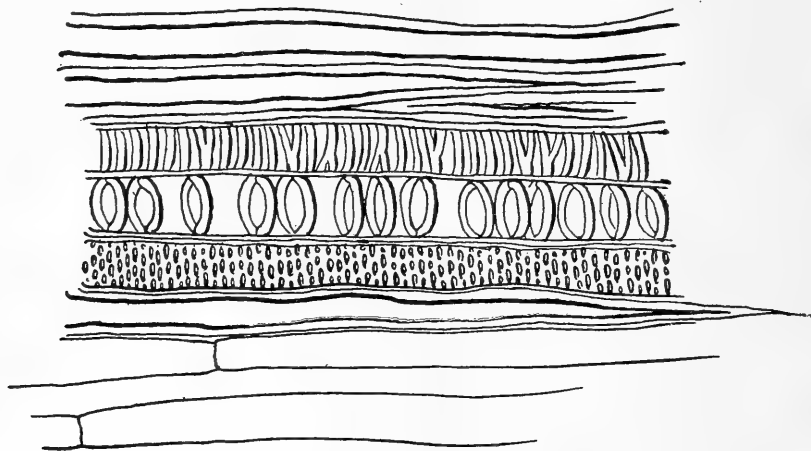


FIG. 3.—Longitudinal section of culm, $\times 480$, showing spiral and porous vessels, stereome, and thin-walled parenchyma.

Sayula, State of Jalisco; Morelia, State of Michoacan; Nevada de Toluca, Ixtaccihuatl, Popocatepetl, Salazar, Cima, Federal District of Mexico; Eslava, State of Mexico; Mount Orizaba, San Marcos, San Andres, and San Miguel, State of Puebla.

Zacaton grows most profusely in the mountain regions east and west of the City of Mexico. It is especially luxuriant in the districts around Sayula and Toluca, in the States of Jalisco and Mexico, respectively (it will be remembered that the original collection of Humboldt and Bonpland was made on the mountain of Toluca), while the finest quality of roots is now said to be harvested around Uruapan, in the State of Michoacan. The grass is generally considered a pest, but a few attempts to subject it to crude methods of cultivation are reported to have given good results. It is perennial,

¹ Many of the data in this and the following paragraphs regarding distribution, climate, and the harvesting of the roots have been secured from Mr. A. McEwen, Frederick, Md.

and after the rainy season sends up new shoots profusely. These are relished by cattle while the tops are immature. Soon, however, the tops become so tough that stock refuse to eat them. The growth is almost entirely a wild one from self-sown seed. The mature panicles are not unlike those of timothy. Unless checked by fire, cultivation, or the harvesting of the roots, rice-root grass soon covers a field solidly. It is not uncommon to find areas many square miles in extent covered densely with this wild grass. One of the fields harvested by Mr. McEwen was 3 miles wide and 7 miles long, covered almost entirely by a relatively pure stand of *Epicampes macroura*.

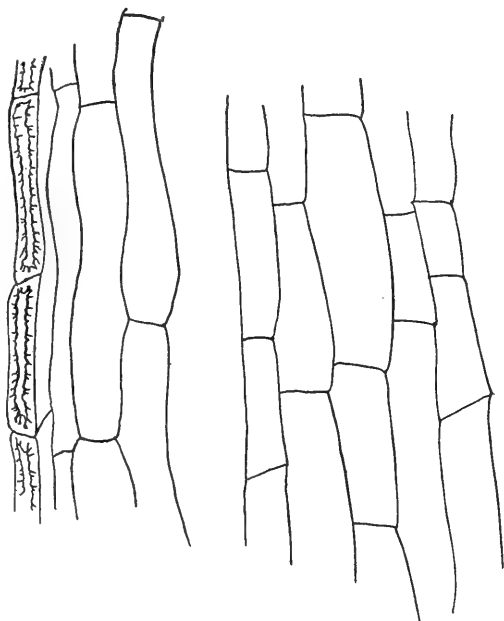


FIG. 4.—Longitudinal section of a culm, $\times 343$, showing sclereids and pith.

The information that has been secured indicates the possibility of growing this grass successfully in some localities in the Southwest, especially for paper-producing purposes. Three allied species grow scatteringly from Texas to California.

Regarding the climate that prevails in the sections where zacaton-root harvesting is extensively carried on, Mr. McEwen states:

We have no means of determining the rainfall, but there is a considerable quantity of rain, and the morning dew is almost as heavy as the average small shower in the States. In Sayula it rains about three months of the year, the rest of the year being dry, and one of the most beautiful climates that you can possibly imagine.

The rains, when they come, are very heavy and in the middle of the day the thermometer registers about 80° F., but it is not uncommon for it to drop to 50° at night; this is a good average through the

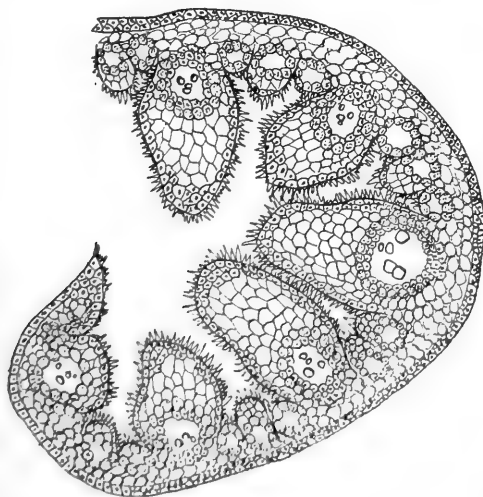


FIG. 5.—Cross section of a leaf blade, $\times 80$.

summer, for my brother says that all through the present summer it has been cold enough for an overcoat at night in the town of Sayula, where he resides. During January, he says that it reaches to near zero and at 10 o'clock the next day it is up to 70° again.

Mr. O. F. Cook corroborates Mr. McEwen's observations regarding the relative coolness of the climate in which this grass thrives. In Guatemala, where the former has noted the plant especially, he found the same conditions.

Figure 8 shows a comparatively sparse stand of zacaton on the Vulcan de Agua, near Antigua, Guatemala, one of the early localities from which the plant was collected.

Figure 9, from a photograph taken in Guatemala, shows the grass promptly claiming the neglected portion of a formerly cultivated field on a terraced hillside along the road between Totonicapam and

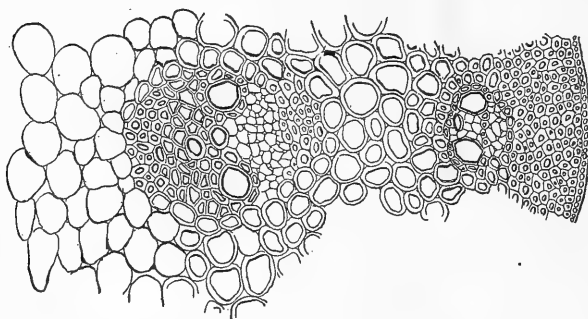


FIG. 6.—Cross section of a leaf blade, $\times 240$, showing hypodermal stereome, the large water-storage tissue, the palisade tissue, and the mestome surrounded by a parenchyma sheath and a thick-walled mestomesheath.

Quezaltenango, Guatemala, showing also in the middle distance, on the mountain slope below the pines, a characteristic wire-grass formation contending with the pines for supremacy. Both of these figures are from negatives

made under the direction of Mr. Cook by Mr. C. B. Doyle, of the Bureau of Plant Industry.

The grass is said to flower from August to October, depending upon altitude and other conditions, and usually attains a height of 5 to 7 feet. The usable portions of the roots vary in length from 2 to 30 inches. The diameter of the roots range from one sixty-fourth to three thirty-seconds of an inch. They are gathered at all seasons of the year, peons digging them up with an implement resembling a hoe in shape. After washing, cleaning, and drying, the roots are cut from the grass, graded, and separated according to quality, length, and color, and finally baled ready for shipment. Vera Cruz and Tampico are the chief exporting ports, while France, Germany, and the United States are the chief users of the brushes into which the roots are manufactured. Roots of a pale yellow, a decidedly characteristic color, are preferred by the trade. It is estimated that an acre of grass yields a ton of marketable roots and at least 3 tons of tops. At present the tops are not used in any way. It seems likely that root operators might find it worth while to attempt the utilization

of the grass for pulp manufacture in sections where there are large acreages of luxuriant growth and where the cost of collecting the raw material in commercial quantities is not prohibitive.

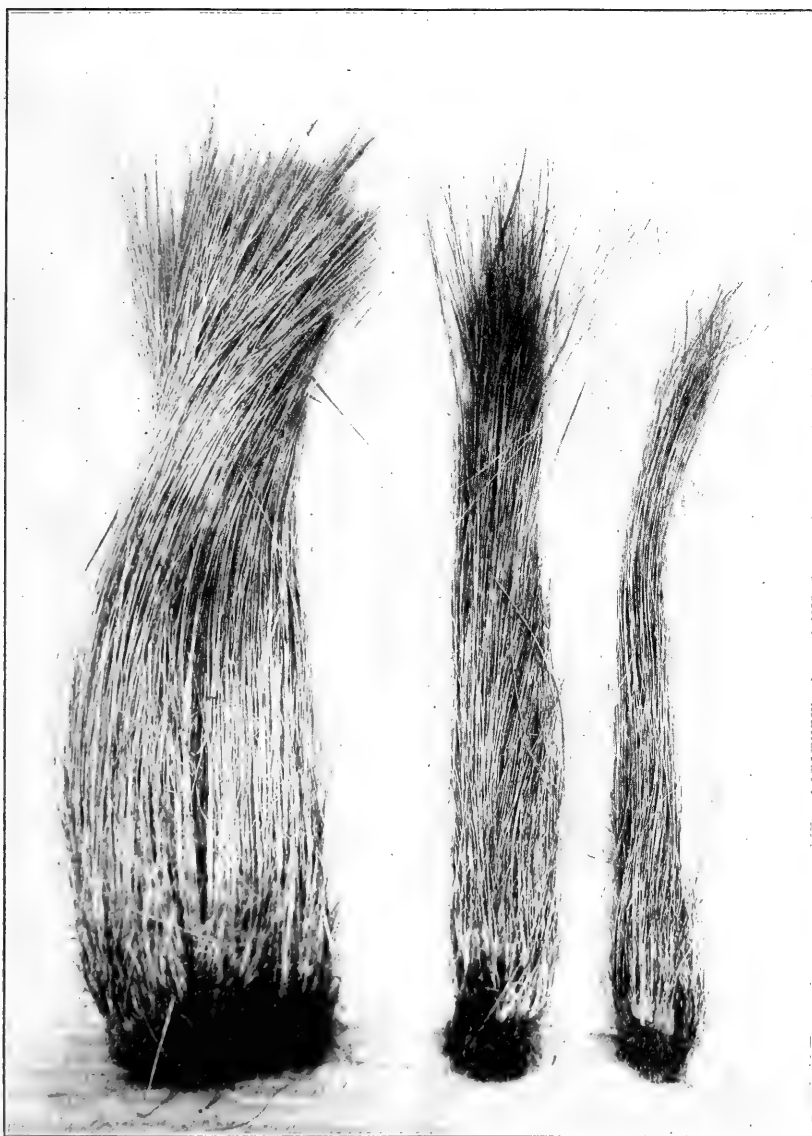


FIG. 7.—An average tuft and two small tufts of zacaton grass.

The writers have not as yet been able to obtain accurate figures as to the production of roots in pounds, but such figures as are available indicate a total production of from three to five million pounds per

annum. The cost of producing the roots per pound is, roughly, as follows:

Ground rent, or the harvesting privilege.....	\$0. 04
Harvesting.....	.01½
Cleaning and topping.....	.04
Hauling to primary shipping point.....	.00¾
Freight to New York.....	.02

If the tops can be gotten out economically and reduced to pulp without an expensive freight haul, there would seem to be no question as to the promise of this material, which at present is purely a waste



FIG. 8.—A sparse stand of zacaton on the Vulcan de Agua, near Antigua, Guatemala.

product. It would be unwise to attempt to put a value on the tops delivered at a pulp mill, but it can be said that properly harvested esparto from Spain, Algeria, and Tripoli brings from \$17 to \$23 per ton in the English market. A good zacaton range can be profitably gone over for root brush material every third year.

LABORATORY TESTS OF PULP PRODUCTION.

An investigation of the paper value of any new fibrous plant can be conveniently separated into two distinct divisions, just as the manufacture of paper is commercially divided into two distinct branches. The first division embraces the separation and purifica-

tion of the plant-cellulose fibers, while the second division concerns the physical treatment and formation of these fibers into the finished sheet.

The separation and purification of the cellulose fibers is necessarily investigated first, and should be brought to as satisfactory a con-



FIG. 9.—Zacaton grass claiming a formerly cultivated field on a terraced hillside near Quezaltenango, Guatemala.

clusion as possible before actual paper making is considered. This investigation is most advantageously, almost necessarily, pursued in the laboratory, where conditions can be produced and accurately controlled. Fiber separation or production is effected commercially by one of the four following processes: The mechanical process, by

grinding; the sulphite process, by acid hydrolysis; the caustic-soda process, by hydrolysis with caustic soda; and the sulphate process, by hydrolysis with sodium hydrate and sulphid.

From previous general knowledge of the paper value of fibrous plants and from the similarity of zacaton to known species, it was decided to investigate this material by the soda process, which consists in subjecting the material to the action of a caustic-soda solution at moderately high temperature for a definite length of time, which operation is technically known as cooking. Since the soda solutions at the temperatures required exert a steam pressure of 50 to 100 pounds to the square inch, the cooking is effected in large, strong steel cylinders, known as digesters, which are of two general types, the upright stationary and the horizontal rotating. The preliminary cooking of zacaton was conducted in an autoclave, simulating the conditions of the upright stationary digester. The autoclave was of the regular laboratory type, of 7½-liter capacity, composed of a rigid stand supporting the spun-copper autoclave shell, which could be securely closed by clamping on a bronze head or cover, the seal being secured by polished surfaces between the body and the head. The head was provided with a pressure gauge and thermometer well. A gas burner underneath the shell served to heat the charge to any desired temperature or pressure.

The method of operation is to place a certain weight of material in the body, to cover with a soda solution containing sufficient caustic soda to completely reduce the material, to securely close the autoclave, and, by means of the gas burner, to heat the entire charge to a definite temperature or pressure. This pressure is maintained the required number of hours, after which the charge is allowed to cool and the contents are removed and washed free from the dark-colored spent soda solution known as black liquor. Undercooked pieces of grass, which are invariably present, are separated from the pulp by screening through a No. 10 screen, in which the slots are 0.01 of an inch wide.

If the material under examination contains pith cells which by reason of their high percentage or quality tend to impart undesirable qualities to the finished sheet, it will be necessary to separate them from the true fiber at this point. Separation can readily be accomplished by manipulating the pulp on a 60 or 70 mesh wire cloth with a stream of water, whereby the small pith cells are washed away, leaving the long, true fibers on the wire. In the case of zacaton it does not appear necessary or advisable to separate the pith, and it was done only in cook No. 1.

In autoclave cook No. 1, 404 grams of grass, bone-dry basis, were treated with 24.4 per cent of caustic soda at a concentration of 19.7

grams of caustic soda per liter for 6 hours at a steam pressure of 90 pounds per square inch. It was very apparent that the long fiber, and even the screened fiber, was superior in quality to that of many other fibrous plants which had been tested, the soft feeling and bright luster being very noticeable.

In cook No. 2, 400 grams of grass were treated with 23 per cent of caustic soda at a concentration of 29 grams per liter for $7\frac{1}{2}$ hours at a steam pressure of 90 pounds per square inch. The yield and general appearance of the fiber from this cook were very similar to those of the one preceding, and the conditions of treatment were possibly all that could be desired with this type of digester. Further economy of

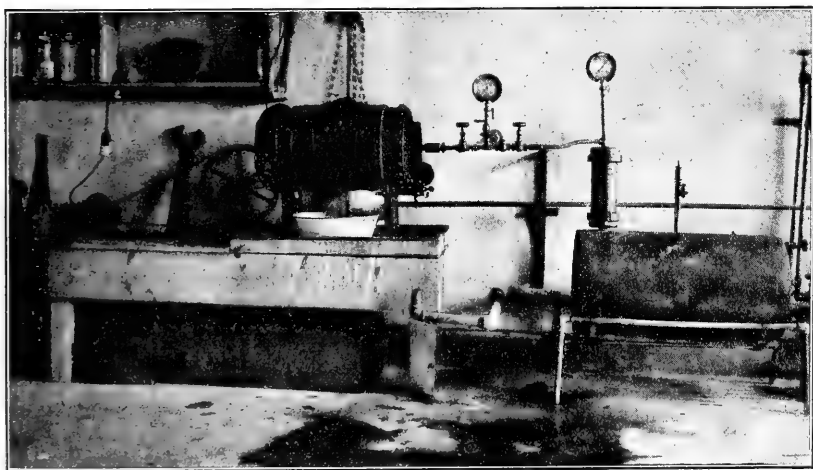


FIG. 10.—Experimental rotary pulp boiler.

treatment might be obtained with the rotary type of digester, where a lower percentage of caustic soda and a smaller volume of solution in proportion to the grass used would be possible. This method gives a more uniform pulp and affords a somewhat cheaper recovery of the spent soda, which is essential to the economic application of the soda process.

The rotary type of boiler employed was a $\frac{1}{4}$ -inch steel shell, $12\frac{1}{2}$ inches in diameter by $29\frac{1}{2}$ inches in length (38 liters in capacity), supplied with a hand hole and screw cap and mounted so as to rotate on its long horizontal axis one revolution per minute. (Fig. 10.) The charge was heated by gas burners underneath and controlled by a thermometer inserted in a well extending from the end of the shell into the center of the charge. Table I shows the yield of fiber obtained from these two cooks.

TABLE I.—*Fiber yields from two bone-dry cooks of zacaton grass, using different concentrations of caustic soda under a steam pressure of 90 pounds to the square inch.*

Cook.	Quantity.	Caustic soda.		Time boiled.	Pressure.	Yield.				
		Per liter.	Per cent-age.			Screen-ings.	Screened fiber.	Pith.	Long fiber.	Total fiber.
No. 1.....	Grams. 404	Grams. 19.7	24.4	Hours. 6	Pounds. 90	Per ct. 4.7	Per ct. 35.4	Per ct. 7.5	Per ct. 27.9	Per ct. 40.1
No. 2.....	400	29.0	23.0	7½	90	4.6	37.1	.....	.....	41.7

Cook No. 3 was made in the rotary by treating 2,400 grams of grass, bone-dry weight, with 19 per cent of caustic soda at a concentration of 71 grams per liter for 6 hours at a steam pressure of 80 pounds per square inch, which gave a yield of 50.8 per cent of total fiber. The pulp was very uniform, soft, and of good appearance, and the cooking conditions were not as harsh or expensive as those for commercially treating poplar wood.

Cook No. 4 was made from a bale of zacaton which was received in a dry but very moldy condition, and the grass was quite brittle. A charge of 2,400 grams was treated with 19 per cent of caustic soda at a concentration of 70 grams per liter for 6 hours at a steam pressure of 80 pounds per square inch, giving a yield of 49 per cent of total fiber. It was impossible to distinguish any difference in quality between the pulp from the sound and that from the moldy grass, the fungi apparently attacking only the less resistant forms of hemi-celluloses.

Cook No. 5 was made by treating 2,000 grams of zacaton with 18 per cent of caustic soda at a concentration of 70 grams per liter for 5 hours at a steam pressure of 90 pounds per square inch, giving a yield of 44.6 per cent of total fiber.

Cook No. 6 was made by treating 2,400 grams of grass with 16 per cent of caustic soda at a concentration of 70 grams per liter for 5½ hours at a steam pressure of 90 pounds per square inch, giving a fiber yield of 47.7 per cent of the total bone-dry grass. The expenditure of soda and time was very moderate, the yield was very fair, and the general appearance of the pulp was remarkably good.

MICROMEASUREMENTS OF FIBER AND OTHER CELLS.

Table II shows the comparative measurements of the cells of zacaton grass. The measurements were made on the screened stock from which paper No. 76 was made.

TABLE II.—*Comparison of the cell measurements of fibers and other cells of zacaton grass.*

Measurement.	Parenchyma of pith.		Long epidermal cells.		Parenchyma.		Bast.	
	Length.	Width.	Length.	Width.	Length.	Width.	Length.	Width.
Maximum.....	Mm. 0.112	Mm. 0.072	Mm. 0.079	Mm. 0.011	Mm. 0.223	Mm. 0.058	Mm. 3.0	Mm. 0.013
Minimum.....	.072	.057	.072	.011	.162	.018	.5	.005
Average.....	.092	.061	.075	.011	.193	.038	1.7	.0085

The true fiber (fig. 11) has remarkably good felting qualities, but its length is less than that of esparto, which varies from 1.5 to 1.9 millimeters.

CHEMICAL INVESTIGATION OF THE GRASS AND PULP.

In cooperation with the Department of Commerce, an investigation of the chemical nature of zacaton grass and pulp in regard to such points as have a bearing on their paper value was conducted at the Bureau of Standards.¹

The pulps examined were from cooks 7, 8, 9, and 10. The report of this chemical investigation, which needs no comment, is given in full, as follows:

1. *Original straw*.—(a) Ash; (b) moisture; (c) ether-alcohol extract; (d) water extract; (e) cellulose by (1) Cross and Bevan chlorin method, (2) Cross and Bevan dilute nitric method, (3) Renker's chlorin method; and (f) loss on boiling with dilute caustic soda.

It was found necessary to grind the straw very fine, on account of the lack of homogeneity of the samples. The largest samples practicable with the unground straw gave widely varying results, so recourse was had at once to grinding all the straw in a clean coffee mill before analysis.

Analyses for comparative value should refer to dry material; hence the moisture was determined first to be 4.8 per cent. The ash gave 9.1 per cent in one determination and 8.8 per cent in another. In both cases a very large proportion of the ash was silica, as shown

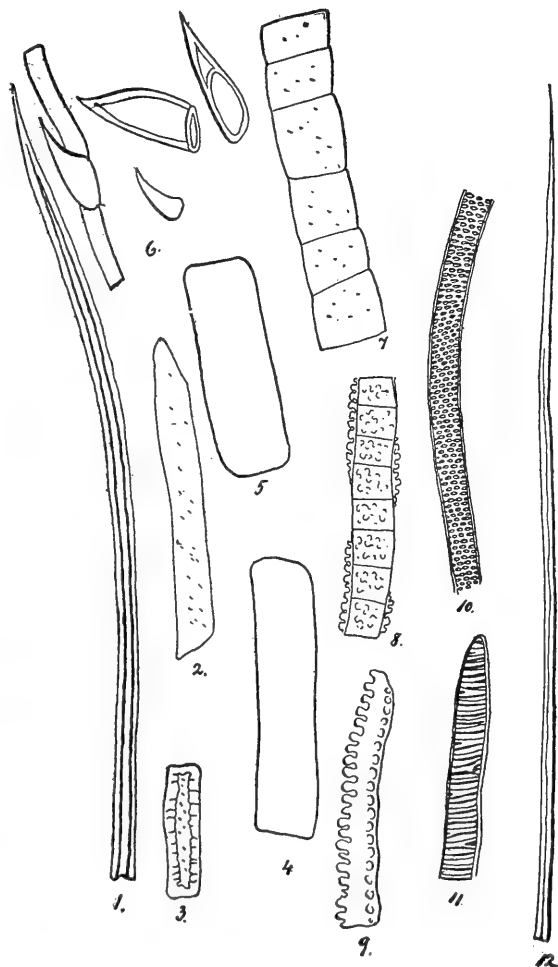


FIG. 11.—Pulp of *Epicampes macroura*, X 352: 1, Bast; 2, porous parenchyma; 3, sclereid; 4 and 5, parenchyma; 6, modified epidermal cells; 7, parenchyma of pith; 8, short epidermis cells; 9, long epidermis cells; 10, pitted trachea; 11, annular trachea; 12, bast.

¹ The chemical work on zacaton was done by Mr. George S. Tilley, at that time cellulose expert at the Bureau of Standards, United States Department of Commerce.

by volatilizing with hydrofluoric acid. In one case silica was 7.5 per cent of the original straw and in the second 6.5 per cent.

(a) This is a rather high ash content and a particularly large amount of silica, in comparison with the analyses of other straws published by Mayer, Müller, Hofmeister, and others. It fuses in a glass with the other constituents of the black liquor if sharply ignited, but on slower ignition gives a cake which easily falls to pieces on extraction with water. There will probably not be silica enough to interfere with the usual soda recovery on the large scale, especially if some of the English silica-removing processes are used. A trial of this point is, however, advisable where so much silica is found. This has, for example, nearly five times as much silica as esparto grass, as analyzed by Müller.

(c) Ether-alcohol extraction was carried out, not so much for the purpose of securing very valuable information, but in order to note abnormality, if any existed. One analysis gave 0.8 per cent loss, and a second 0.9 per cent, the nature of the extract not being further investigated. It is usually reported as fat, wax, and chlorophyll.

(d) The ether-extracted straw was further extracted for 14 hours with water in the modified Wiley extractor, which extracts at the temperature of the boiling solvent. The loss under this treatment was 5 per cent in one case, and 5.6 per cent in the second. As straws go, this shows a high degree of resistance, it being possible to extract as much as 70 per cent of some straws in this way. This value for *Epicampes* puts it between rye and wheat straw, roughly speaking, although of course there are wide variations in individual cases.

(e) "Cellulose" was determined by three methods; in each case the ash in the resulting product was determined and the ash-free white fiber resulting from the process followed was reported as "cellulose." No process now in use can claim to give a "normal cellulose" from straw or wood, and the significance of the per cent of "cellulose" reported is always relative to the analytical method followed.

(f) According to the original Cross and Bevan¹ method, as described in their book, the yield of "cellulose" averaged 41 per cent. Renker, in his recent book,² advises omitting the treatment with dilute alkali both before and after chlorination. The yield of fiber by this method was 51 per cent average. Cross and Bevan claim incomplete removal of lignin by this method, but Renker is certainly right in saying that the dilute alkali attacks the cellulose considerably. As a test of this, weighed samples of the straw were boiled 50 minutes with 1 per cent caustic soda, then filtered, dried, and weighed. The losses averaged 45.1 per cent on the bone-dry straw, with a residue of 54.9 per cent. This certainly leaves little for the chlorin to do in bringing the residue down to the 41 per cent found. It is probable that the true value lies between the two. Concordance in results may be obtained by either method, but of course adds nothing but confirmation of care in performance of the work.

The method of heating for 7 hours at 70° with 10 per cent nitric acid gave white residues (ash free) averaging 39.3 per cent. This is no doubt a minimum value and agrees fairly well with the results of the drastic original Cross and Bevan procedure.

2. *Blow-pit stock*.—Loss on bleaching was determined on the long-fiber unbleached stock. The determination is necessarily crude, because (1) if the stock be dried the chemical nature of the cellulose is changed and the bleaching may have a widely different effect, and (2) the water in the undried stock is about as serious a source of error. Determinations were made on both dried and undried stock. As nearly as possible, average samples of the undried stock were taken and moisture determined in some, while others were bleached.

Limit cases were taken with (a) strongly alkaline bleach, with much active chlorin; (b) slightly alkaline, with a small amount of free chlorin. With the stronger bleach

¹ Cross, C. F., and Bevan, E. J. *A Text-Book of Paper-Making*. 411 p., illus., 2 fold. pl. New York, 1907.

² Renker, Max. *Ueber Bestimmungsmethoden der Zellulose*. Aufl. 2, 107 p. Berlin, 1910.

the losses ran about 20 per cent, while with the more dilute they were from 8 to 10 per cent, with, as was noted, a large factor of possible error. The ordinary bleaching practice would give results nearer the lower limit, if anything.

The blow-pit stock from which the pith had not been separated did not bleach to a good color, even on long treatment. The loss in weight in one case which was weighed was 12.5 per cent, but the stock was not up to a pure white—rather a light cream color. This was due partly to the depth of coloring of the cooked pith and its resistant nature. The strongly resistant nature of the pith is seen by comparison of the results of dilute alkali and acid treatment with their effect on the original straw.

The loss on boiling the pith 1 hour with 1 per cent caustic soda was 18.5 per cent in one case and 17.8 per cent in another. The straw lost 45 per cent under similar treatment, and the pure bleached fiber 20 per cent.

The loss on heating the pith 7 hours at 70° with 10 per cent nitric acid was 18.3 per cent in one case and 17.9 per cent in another, while the straw lost 61 per cent and the pure bleached fiber lost 10 per cent under the same treatment. The necessity of removing the pith, even at the expense of some fiber, is apparent. There was quite a little fiber in the sample of pith, as shown by shaking up a sample with an excess of water, but no method of quantitatively separating the two has as yet suggested itself, unless fractional levigation or filtration may succeed in some form later. Chemically, there is not enough difference to effect even an approximate separation.

3. *Black liquor*.—The black liquor resulted from cooking *Epicampes* straw in an autoclave at 90 pounds for 7½ hours, using 23 per cent caustic on the straw weight, at concentration of 23.9 grams per liter. It was investigated for specific gravity, percentage of dissolved solids, saccharine matter, nitrogenous matter, ash, and total organic matter.

The specific gravity of the liquor was 1.046. It had 9.9 per cent total solids dissolved by one determination, and 10 per cent according to a second. Of this, 2.89 per cent should be the original caustic soda (of course, somewhat altered by combination with silica, etc.). A determination of the ash of the evaporated residue corroborated this; 6.2 per cent of the residue burned away in the blast, leaving 3.8 per cent ash, the 6.2 per cent being, then, total organic matter. The amount of ash does not by any means account for the silica of the straw, even assuming that half of it is left in the finished paper. It is probable that much of it is loosened by the cook and is washed away as a fine suspension.

A Kjeldahl analysis of an evaporated residue showed 2.1 per cent "proteid," using the usual factor in calculation from the ammonia found; that is, there was about 0.2 per cent proteid in the liquor before evaporation.

The addition of mineral acid to the black liquor gave a voluminous precipitate, consisting of acid cellulose, lignic acids, and some silicic acid. The amount of the precipitate was 4.8 per cent of the black liquor, leaving, then, 1.4 per cent organic matter in the filtrate.

The filtrate was examined for sugars. In 100 c. c. of the filtrate only 33 milligrams of sugar were present, calculated to dextrose. Probably the remainder in solution was levulinic acid, humic acids, acid-soluble modifications of cellulose, and similar products of the breaking down of the complex substances in the straw, but their small quantity and lack of value after identification argued against the necessarily long and laborious task of isolating them, even if they could be identified.

Conclusion.—The result of an investigation like the present one on substances of this nature gives necessarily only a general impression rather than a summary of definite and precisely measurable constants. In general, it may be said that *Epicampes macroura* gives a commercially practical yield of rather unusually high-grade paper fiber, with no particular trouble to be expected except from pith and silica in the process of manufacture.

CELLULOSE FROM ZACATON.

The sample sent for examination was bleached pulp of *Epicampes macroura* in the form of waterleaf sheets. The purpose of the work upon it was to determine the nature of its cellulose as completely as possible.

First, qualitative tests were tried. (a) Fuchsin-sulphurous acid (Schiff's reagent) turned a bit of the pulp pink on standing a few minutes. (b) Sachsse's solution (alkaline $\text{HgI}_2, 2\text{KI}$) was reduced on boiling with the pulp. (c) Fehling's solution was reduced on boiling with the pulp. (d) Vitz's methylene-blue test (boiling a bit of the pulp for 15 minutes with 0.5 per cent aqueous solution of methylene blue) dyed the pulp deep blue, which was not removed by long washing. A bit of pure rag paper was put in the dye at the same time, as a check. It dyed light blue and washed nearly white under the same conditions of treatment. (e) Phenylhydrazin acetate boiled with the pulp gave a yellow hydrazone. (f) Ferric ferricyanid (Cross and Bevan) gave a blue precipitate with the pulp on standing some minutes. According to Cross and Bevan, this reaction is a quantitative measure of lignin. Later work has shown, however, that oxycellulose gives the same precipitate. (g) On distilling from a suspension of the pulp in hydrochloric acid of 1.06 specific gravity and adding a phloroglucin solution to the distillate, a large amount of furfural phloroglucid was precipitated. These reactions show conclusively that the sample contained oxycellulose in considerable quantity.

As oxycellulose is quite sensitive to attack by many destructive agencies, it was of importance to determine how much was in this sample from *Epicampes macroura* in relation to other celluloses. In the present state of knowledge (which, unfortunately, is rather a state of ignorance) of the constitution of cellulose, it is impossible to say how much of any given sample is oxycellulose. However, it is easy to compare samples and determine which has more or less of it.

Accordingly, comparative quantitative determinations were made of (1) copper number and (2) furfural yield on the cellulose from *Epicampes macroura*, a bleached soda poplar pulp, and on cotton "cellulose" simultaneously. The "copper number" of Schwalbe is the number of grams of copper precipitated by boiling 100 grams of the pulp in question for 15 minutes with Fehling's solution, under certain definite conditions of concentration, heating, and so on. In the absence of other reducing substances it is an admirable measure of oxycellulose; hence, it was used here with a modified Low volumetric method of determining the copper instead of Schwalbe's slower and no more accurate electrolytic method.

It is at once evident that the *Epicampes* cellulose contains slightly more oxycellulose than the poplar pulp and much more than the cotton. (Contrary to the commonly accepted belief, the writers have found most cotton cellulose to contain a little oxycellulose, as shown by many tests.)

For further confirmation and comparison, simultaneous quantitative estimations of the furfural yield from the same cotton, poplar pulp, and *Epicampes* pulp were made, following the method of Flint and Tollens. This, of course, would not be applicable in the presence of wood gums or various other pentosans or furfurosans, but was here applicable because the other furfural-yielding groups were absent.

The numerical results of these two analyses are shown in Table III.

TABLE III.—*Copper number and furfural yield of samples of cotton, poplar pulp, and Epicampes pulp in two determinations.*

Sample.	Determination No. 1.		Determination No. 2.	
	Copper No.	Furfural.	Copper No.	Furfural.
		<i>Per cent.</i>		<i>Per cent.</i>
Cotton.....	1.25	0.40	1.31	0.50
Poplar pulp.....	4.26	10.01	3.82	10.00
Epicampes pulp.....	4.58	10.92	4.39	10.62

It is here again evident that Epicampes cellulose is close to poplar pulp in oxycellulose content and contains slightly more of it.

This being so, the Epicampes cellulose should be more sensitive to attack by hydrolytic and oxidizing agents. In verification of this, determinations were made (*a*) of the action of alkaline solutions and (*b*) of nitric acid on all three celluloses, using the same three of the preceding work. First, the action of a 1 per cent aqueous NaOH solution on the three celluloses was tried. Weighed samples were boiled 60 minutes with a large excess of the solution, then filtered, washed, dried, and again weighed.

This verifies, in so far, the prediction from the relative amounts of oxycellulose. Next, the action of concentrated NaOH solution was tried, according to the usual procedure for determining "loss on mercerizing." The agreement here is as good as can be expected of this reaction, because of the slow penetration and uneven action of the cold concentrated solution. It shows the same relation between the celluloses, although more roughly than preceding determinations.

Next, the action of nitric acid was tried, (*a*) using "nitrating acid" and determining "gain on nitration" in the usual manner and (*b*) using 5 per cent HNO₃ at 70° C. for 7 hours. The resistance to combined oxidizing and solvent action of the nitrating acids (equal parts of concentrated sulphuric and fuming nitric acids) is very evident in the predicted order. Table IV shows the numerical results of these tests.

TABLE IV.—*Action on cotton, poplar pulp, and Epicampes pulp of a concentrated nitrating mixture and dilute and concentrated solutions of sodium hydroxid.*

Sample.	Determination No. 1.			Determination No. 2.		
	Loss in NaOH, 1 per cent solution.	Loss in NaOH, concentrated solution.	Total yield per 100 grams in nitrating mixture.	Loss in NaOH, 1 per cent solution.	Loss in NaOH, concentrated solution.	Total yield per 100 grams in nitrating mixture.
	<i>Per cent.</i>	<i>Per cent.</i>	<i>Grams.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Grams.</i>
Cotton.....	2.0	7.9	177.7	1.4	9.1	180.7
Poplar pulp.....	12.3	15.4	159.0	12.1	18.2	(¹)
Epicampes pulp.....	19.3	17.3	149.2	19.4	18.4	140.8

¹ Sample exploded during the process of drying.

Next, the action of hot dilute (5 per cent) nitric acid was tested. Weighed samples of poplar pulp and Epicampes pulp were heated for 7 hours at 70° C. with 100 times their weight of 5 per cent HNO₃, then filtered, washed, dried, and weighed. Because of the small amount of Epicampes pulp remaining, no duplicate could be made. The soda poplar pulp lost 6.1 per cent and the Epicampes pulp 10.2 per cent in the process.

This evidence was considered sufficiently complete with regard to the oxycellulose question. The behavior of *Epicampes* pulp with the usual solvents of cellulose was tried, with results as follows:

- (a) Schweitzer's reagent dissolved all but the merest faint trace of the fiber.
- (b) Concentrated sulphuric acid dissolved the fiber quite rapidly and completely, with a very faint darkening in color—not nearly so dark as straw celluloses usually give with sulphuric acid.
- (c) Zinc chlorid in concentrated hydrochloric acid dissolved the fiber more slowly than did sulphuric acid, but quite completely.
- (d) Zinc chlorid solution swelled the fiber, but dissolved it only slowly.

The percentages of ash and moisture were also determined, ash being 2.2 per cent and moisture 4.8 per cent. Both determinations are of minor importance, the ash qualitatively and quantitatively being dependent on the previous treatment of the pulp and the moisture on the atmospheric conditions. The fact that they were not extraordinary had, however, to be determined. The moisture was within 0.2 per cent of that of poplar pulp under the same atmospheric conditions, indicating again the close chemical relationship that has been evident throughout in the comparison of poplar and *Epicampes* pulps, as it is well known that different forms of cellulose have widely differing hygroscopicity. It is, in fact, more closely related to poplar pulp than it is to straw celluloses, like those of wheat or rye. These latter give from 12 to 14 per cent of furfural, for example, while *Epicampes* pulp gave a 10.8 per cent average, poplar giving 10 per cent. The resistance of *Epicampes* cellulose to destructive agents in general is correspondingly higher than that of the usual straw celluloses.

It was next intended to make a methoxyl determination on the *Epicampes* pulp, but microscopic examination showed (1) lignified cells still present and (2) cells in bundles that are usually completely separated by cooking, although only a very little of either. A methoxyl determination would be unfair to the sample when thus undercooked, and so was not carried out.

Direct determination of cellulose by any of the accepted methods is obviously useless here, (1) because the pulp has already been through processes for lignin removal and (2) because the presence of oxycellulose renders impossible a determination of cellulose accurate to 15 per cent, as it is always attacked much more than lignin by the usual reagents. There is no existing accurate method for these conditions.

Carbon and hydrogen determination by combustion would add, perhaps, a little to the already present wealth of evidence of oxycellulose presence, but the relation of furfural yield to carbon percentage is so well known that the carbon could be predicted to a fraction of a per cent. This determination, therefore, seemed needless for the complete characterization of the *Epicampes* fiber.

Hydralcclulose was tested for during the "copper number" determinations, by Schwabe's method, and found absent.

To sum up the net result of these determinations: *Epicampes macroura* bleached pulp is a natural oxycellulose closely related to poplar pulp in chemical properties and considerably superior to the usual straw celluloses in power of resisting chemical attack by destructive agencies.

SEMICOMMERCIAL TESTS OF THE PULP.

Having experimentally determined the cooking conditions and found them to be reasonable and satisfactory and also having determined that the chemical nature of the pulp was satisfactory, the work was continued on a semicommercial scale and was planned to include the actual manufacture of paper. There is a tendency on the part of many to discount the practical value of results obtained

experimentally on a small scale, and doubtless in many cases this attitude is justified. Experimentation on a small scale has its own valuable sphere of usefulness, but great care should be exercised in its commercial interpretation. Therefore, with a view to giving this material a more reliable or commercial paper value the work was continued on a larger scale, more nearly under mill conditions and at a place where the services of actual mill employees could be secured for the work.

The digester employed for this work was of the upright stationary type, measuring about 2 feet in diameter by 10 feet high and heated by direct steam. The cooked charge was "blown" in the regular manner into a blow pit of ordinary construction, where it was drained and washed free from black liquor. After screening in the regular manner the stock was bleached with mill bleach liquor in a beating engine and bleach chest, washed free from bleach residues, made into the desired furnish, and suitably beaten, after which it was run through a Jordan refiner and then to a Fourdrinier paper machine. The greater part of this whole work was performed by the regular mill employees.¹

The material used for the four cooks of this test was dry, but had previously molded to some extent, being the same as that used in cooks Nos. 4, 5, and 6. Table V shows the cooking conditions and the yields of the four cooks.

TABLE V.—*Conditions of cooking and total yields of fiber of four cooks of zacaton grass.*

Cook.	Charge, bone dry.	Caustic soda added.	Concen- tration of caustic soda.	Cooking pressure.	Hours under pressure.	Yield, bone dry, of total fiber.
	<i>Pounds.</i>	<i>Per cent.</i>		<i>Pounds.</i>		
No. 7.....	175	20	41	100	5	38.6
No. 8.....	182	19	90	90	6	33.4
No. 9 ^a	192	18	.....	90	5	44.6
No. 10 ^a	186	16	.....	90	6	45.2

^a The charge in the digester was covered with water and heated to a steam pressure of 50 pounds per square inch for 1 hour, after which the water extract was all drained off and the residue cooked in the regular manner.

The higher yield of total fiber in cooks Nos. 9 and 10 is due to the lower percentage of soda added and the fact that its concentration was lowered by the water remaining in the grass after extraction. The general appearance of the pulp of these four cooks was very similar; they were soft feeling, bulky, and had a very silky luster. Screening was done on a No. 10 cut screen, and in place of a pulp thickener the screened stock was run over the wet end of a Fourdrinier paper machine and taken off at the first press. This procedure left the stock in fine condition to be transferred to the bleach beater.

¹ Much assistance and information was furnished by S. D. Warren & Co., Cumberland Mills, Me.

Screened pulp from the four cooks was combined into one beater charge, heated to about 40° C., and after being thoroughly mixed with bleach liquor to the equivalent of 21 per cent of its bone-dry weight of commercial bleaching powder, was pumped to a bleach chest to exhaust. When the bleach was practically all consumed and the

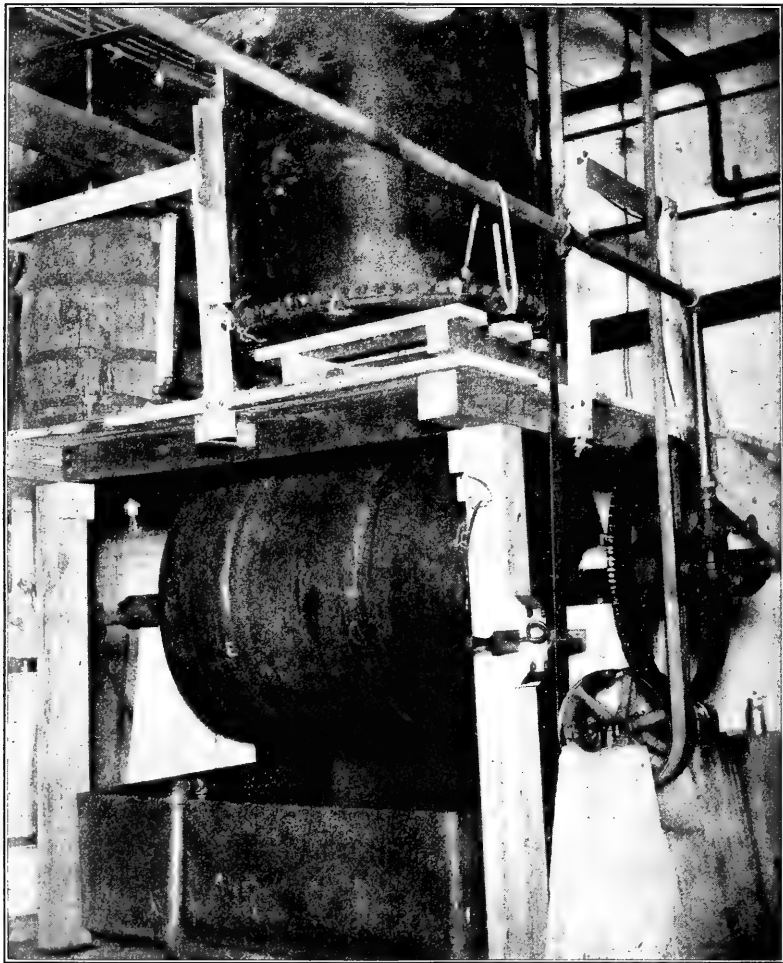


FIG. 12.—Semicommercial rotary pulp boiler.

color of the stock was found to be satisfactory, it was drained and washed free from bleach residues.

The bleached stock was then beaten with a medium brush for 2½ hours, loaded with 25 per cent of clay, sized with a 0.5 per cent resin size and 2 per cent of alum, and run through a Jordan refiner and then to a 30-inch Fourdrinier paper machine speeded to 90 feet per minute. The stock acted very well on the paper machine, giving

very little trouble and producing a machine-finished sheet of good appearance and quality. Physical tests on this sheet, designated as No. 41, are recorded in Table VIII.

Since the installation of a rotary type of digester by this bureau, further tests were made on Epicampes under the more favorable conditions afforded by this method of treatment. The rotary measured 6 feet in length by 4 feet in diameter, and was supplied with a large man head, thermometer well, pressure gauge, steam inlet, and steam relief through the hollow trunnions, and rotated at one-half a revolution per minute (fig. 12). A charge of 350 pounds could be handled conveniently, using a much stronger caustic solution and yielding a more uniform pulp.

The cooked charge was dumped into an iron drain tank underneath, where, by means of a false bottom, the fiber could be drained and washed with no loss. By means of a vacuum under the false bottom, the water could be drained from the fiber uniformly, leaving only 70 to 80 per cent of water in the fiber, in which condition it could be sampled and weighed with a good degree of accuracy. Uniformity of chemical action on the grass was very noticeable and assisted very much in the subsequent operations and quality of the pulp.

The grass used for these tests was of good, medium quality and in perfect condition. Four cooks were made, in order to secure sufficient pulp for a fair trial on the beating engine and paper machine, the cooking conditions of which are shown in Table VI.

TABLE VI.—Conditions of trials of four cooks of zacaton pulp.

Cook.	Grass.			Rela- tion of caustic soda added.	Strength of caustic solution.	Caustic soda added.	Caustic solu- tion added.	Maximum temperature, boiling.		
	Air dry.	Bone dry.						Time to reach.	Heat used.	Time held.
		Per cent.	Pounds.							
No. 11.....	<i>Pounds.</i> 341	90.7	309	<i>Per ct.</i> 19.0	<i>Per cent.</i> 9.18	<i>Pounds.</i> 58.9	<i>Gallons.</i> 77	<i>Hours.</i> 1½	° C. 160 166 166	<i>Hours.</i> 6
No. 12.....	361	91.0	328	20.1	9.18	66.0	86	2	160 166 166	4
No. 13.....	335	90.8	304	20.2	9.18	61.6	81	1½	166 166 166	4
No. 14.....	342	90.8	311	20.3	9.18	63.2	82	1½	166 166 166	3½

As seen by the table, the cooking was controlled by temperature instead of by steam pressure. Since it is temperature and not pressure which induces chemical action, and since steam pressure is indirectly an expression of temperature, it is obviously correct to employ either for control. On account of the presence of more or less air in the steam supply, and on account of gases which are

liberated during the cooking, there is usually more pressure within the digester than the pressure corresponding to the temperature of the charge, and since this false pressure is usually unknown it seems preferable to employ temperature as the control.

The results of the tests are shown in Table VII..

TABLE VII.—*Results of trials of four cooks of zacaton pulp.*

Cook.	Fiber.			Relation of bone-dry fiber.	Causticity of waste solution.	Caustic.		
	Wet.	Bone dry.				Consumed by grass.	Relation of excess.	Relation of consumed to added.
		Per cent.	Pounds.					
	<i>Pounds.</i>			<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>
No. 11.....	686	22.8	156	50.4				
No. 12.....	815	20.0	163	49.7	35.3	12.0	8.1	59
No. 13.....	715	20.1	143	47.0	38.2	11.5	8.7	56
No. 14.....	730	19.8	144	46.3	38.7	11.4	8.9	56

The average yield of fiber at 90 per cent bone dry is 43 per cent of the air-dry grass, which would average 80 per cent bone dry.

The excess caustic soda, 8.1 to 8.9 per cent of the bone-dry grass, is doubtless higher than is necessary, and it would indicate that less soda could have been employed in the cooking.

Pulp charges from the four cooks were remarkably similar in appearance and feeling; they drained and washed with great ease, a property not shared by the pulp of many plants and a fact of great importance in a commercial sense, because of the necessity of washing out and recovering the spent soda.

On screening the pulp charges through a No. 10 cut screen there remained undercooked screenings to the extent of 2.05 per cent of the bone-dry pulp, or 1 per cent of the bone-dry grass. The screened stock bleached easily and to a satisfactory color with the equivalent of 12.7 per cent of commercial bleaching powder.

After washing free from bleach residues, the stock was given four hours' medium brushing in a beating engine (fig. 13) and furnished with 24 per cent of clay, 1.8 per cent of resin size, and 2 per cent of alum.

At the close of the beating operation the charge was whitened by the addition of a small amount of blue or blue and red color, to offset the residual yellow tint invariably present in all bleached stocks.

The finished stock was run through a Jordan refiner and to a 30-inch Fourdrinier machine speeded to 85 feet per minute. Although the stock was a little too "free" to get the maximum felting of the fiber it acted very well on the machine and gave a machine-finished sheet of good appearance and quality. Physical tests of this sheet, designated as No. 76, in connection with those of sheet No. 41 are given in Table VIII.

PHYSICAL TESTS OF ZACATON PAPERS.

It is impossible to grade these papers according to any recognized classification, since the fiber from the zacaton plant is not recognized as the equivalent of any commercial paper stock. From the fact that the chemical examination placed the fiber very close to soda poplar fiber it might be regarded as the equivalent of soda poplar in grading the samples according to any scheme of classification. However, since the endurance of these papers, as well as their behavior under manufacturing conditions, yet remains to be proved, it would hardly be justifiable at present to regard zacaton fiber as the equiva-

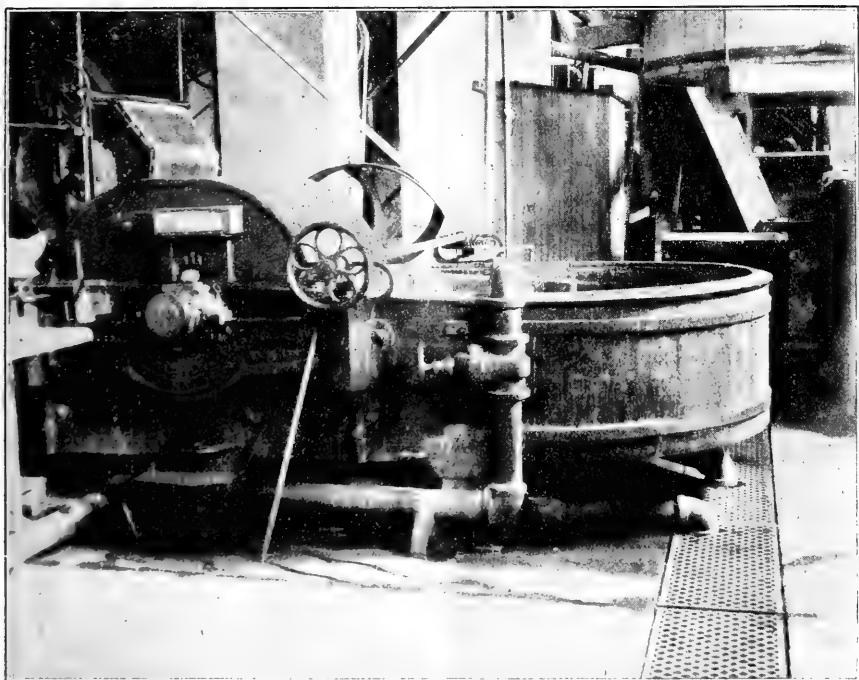


FIG. 13.—Beating machine supplied with washer.

lent of any commercial fiber. It would seem better, on the whole, to consider each physical test by itself in characterizing these special papers.

The system of classification and specifications followed in this work is that established by Veitch,¹ which in the main is used as the basis in the purchase of paper by the Government.

Sample sheets from the semicommercial tests were submitted to the Leather and Paper Laboratory of the Bureau of Chemistry for physical examination. This laboratory makes use of a testing room

¹ Veitch, F. P. Paper specifications. In U. S. Dept. Agr. Rpt. 89, p. 13-51, 4 figs. 1909.

which can be maintained accurately at a constant temperature and relative humidity, conditions which are absolutely essential to comparative and absolute paper testing.

The sample designated as No. 41 was manufactured from the combined pulps of cooks Nos. 7, 8, 9, and 10, and the sample designated as No. 76 was manufactured from the combined pulps of cooks Nos. 11, 12, 13, and 14. The report of the Leather and Paper Laboratory on these samples is shown in Table VIII.

TABLE VIII.—*Physical properties of six paper samples made from zacaton pulp, according to tests conducted by the Leather and Paper Laboratory of the Bureau of Chemistry.*

L. and P. No.	Mark No.	Ash.	Weight, 25 x 38, 500.	Bursting strength.			Strength factor, per wt., 25 x 38.	Thick-ness.	Folding endurance.		Folding factor.	
				Average.	Maximum.	Minimum.			Trans-verse.	Longi-tudinal.	Trans-verse.	Longi-tudinal.
		<i>Per ct.</i>	<i>Lbs.</i>	<i>Pts.</i>	<i>Pts.</i>	<i>Pts.</i>						
30612	41	19.5	51.0	28.0	29.0	27.0	0.55	36	27	42	0.53	0.82
30613	41	19.4	49.5	25.5	27.0	24.0	.52	34	25	39	.51	.79
30614	41	19.2	51.0	27.5	29.0	26.0	.54	37	38	35	.74	.69
30615	76	22.4	52.5	13.0	14.0	12.0	.25	40	4	3	.08	.06
30616	76	22.5	57.0	14.0	14.0	14.0	.25	38	4	3	.07	.05
30617	76	21.4	52.5	13.5	14.0	13.0	.26	39	3	3	.06	.06

Sample No. 41 contains the ash specified for a coated paper, namely, 20 per cent, although some uncoated book papers carry nearly this quantity. Practice varies in the different mills, some using more filler than others for the same general grade of paper. This sample shows a strength factor, which is the bursting strain divided by the ream weight, which is higher than that specified for a first-grade machine-finish printing paper, although the ash is four times that of this grade. The folding factor is likewise higher than is specified for a first-grade machine-finished printing paper.

Sample No. 76, according to the same classification, would fall below the fourth-grade machine-finish printing paper.

It should be noted here, however, that at the time the specifications of Report No. 89 were drawn up, the chief object was to secure better papers in general for the use of the United States Government. The specifications, therefore, are somewhat different and more rigorous than would have been the case had it been the intention to apply them to the general run of commercial papers.

According to present commercial usage, sample No. 41 would be regarded as much better than a first-grade machine-finish printing paper and No. 76 would be classed as a second-grade machine-finish printing paper.

CONCLUSION.

Zacaton grass may prove to be a valuable paper stock, although at present it is a waste product and flourishes in a region remote from the paper-manufacturing sections.

The grass can be chemically reduced to paper stock by the soda process under less drastic and less expensive conditions than those employed for the reduction of poplar wood.

The well-known process, methods, and machinery employed for the manufacture of pulp from poplar wood are entirely suitable for the treatment of this material. In place of the wood-sawing, chipping, and screening machinery, a grass cutter, and possibly a duster, is required.

A production of 43 per cent of air-dry fiber from the air-dry grass is regarded as a very good yield, the fiber yield from poplar wood being from 46 to 48 per cent, and from esparto 43 per cent.

For bleaching the stock it has been found necessary to use more bleaching powder than in the case of poplar stock.

Paper manufactured from this stock has shown physical tests equal to those of a first-grade machine-finish printing paper.

The paper has a very satisfactory appearance and feeling. It is realized that in these two semicommercial tests the maximum possibilities of this material in all probability have not been attained, and better results may reasonably be expected. Moreover, an experienced mill organization after a few months of operation would learn the qualities of the stock and be in a position greatly to improve the product.

It would not be advisable, nor even possible, from the work here described, to make any estimate of the cost of manufacture or the value of the product. Such data can be secured only by extensive experimentation on a semicommercial scale or by actual mill operations.

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A. C. TRUE, Director



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PROFESSIONAL PAPER

November 9, 1915

DIGESTIBILITY OF SOME ANIMAL FATS.

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Nature of the diet.....	2	ton fat, butter.....	5
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INTRODUCTION.

Notwithstanding the fact that fats are ordinarily one of the principal sources of energy in the diet and are two and one-fourth times as effective for this purpose as either protein or carbohydrates, their use in the diet has received less attention by investigators, and is consequently less perfectly understood than that of other nutrients.

It has generally been taken for granted that when eaten in favorable combinations fats are thoroughly assimilated and that the different kinds do not vary enough in this respect to affect materially the amount of energy which the body derives from them. The recorded experimental data, however, are not conclusive on this point. Experimental data are also very limited on another point which is a matter of particular interest at the present time, when the increased demand for culinary and table fats tends to bring into the market kinds which have hitherto been used little if at all, namely, the relation of melting point to thoroughness of digestion, particularly with respect to fats of high melting point.

It is true that many digestion experiments have been carried on with food materials such as milk, cheese, meat, etc., which contain much fat, but relatively few dealing directly with culinary and table fats have been reported and only a small proportion of these have been made under comparable conditions, and while it is also true that the melting point of fats has been very generally and accurately deter-

NOTE.—This bulletin records studies of the digestibility and melting point of lard, beef fat, mutton fat, and butter, and is primarily of interest to students and investigators of food problems.

mined it has not been possible to correlate melting point with digestibility in an exact way on the basis of experiments hitherto made.

The practical importance of further investigations on the subject is indicated by the fact that the common domestic practices in the use of fats, as of other food materials, is at present based very largely on empirical knowledge, and quality in the resultant product depends more upon experience and acquired skill than it does upon knowledge of the physical and chemical properties of the ingredients used and of their relation to the desired object. Yet it is obvious that the whole matter is one which can not be definitely understood, standardized, and controlled unless such knowledge is available. A full understanding of the materials, of the nature of household methods of handling them, and of the resulting effects is necessary as a basis for real economy as well as for more rational and satisfactory use of foodstuffs. The right use of food materials must be governed also by a knowledge of their digestibility and their value as sources of energy available to the body. Neither can one overlook the modifications which are due to the combination of ingredients into foods and to the combination of foods to form meals.

It seemed desirable, therefore, from both the scientific and the practical standpoint to study the digestibility of the more common culinary and table fats prepared in a comparable manner and incorporated in a uniform basal ration. It was with this idea in mind that the digestion experiments with four of the more common animal fats reported in this bulletin were undertaken. These experiments form part of an extended study of the food value and household uses of animal and vegetable fats of different sorts, having to do with (1) the thoroughness of digestion of the fats, (2) the specific dynamic effect of a diet rich in fats of different kinds, (3) the relation of the available (net) to the total (gross) energy values of fats, and (4) the relation of domestic ways of using fat to the quality of foods.

NATURE OF THE DIET.

The experiments here reported were made with beef tallow, mutton tallow, lard, and butter, which were purchased in the open market. The butter was a good commercial grade and was used as purchased.

The beef, mutton, and pork fats were kidney fats. A fairly large quantity of each was rendered in the laboratory in order to provide uniform material for use in each series of experiments. The fat was cut into small pieces, freed from any noticeable muscular tissue, and finely ground in a meat cutter such as is used in the home. It was then rendered in a double boiler, when it was found that the fat separated readily from the inclosing tissues (the temperature during rendering did not quite reach 100° C.). The fat was finally strained through medium fine huckaback and heated, but not much above

the temperature of boiling water, to drive off surplus water and thus improve its keeping qualities. Care was exercised not to heat the fat too high.¹ Judged by the usual household tests, the resulting product in all cases was most satisfactory, being of good color and flavor and free from sediment.

As sufficiently large quantities of the fats to be studied could not be consumed in the natural state, a method of preparing them for eating was sought. The most satisfactory one found was to incorporate the fat in a blanc mange or cornstarch pudding. This was best prepared by cooking skim milk, to which sugar and a considerable quantity of a caramel solution had been added, in an ordinary double boiler, at as high a temperature as could be reached (nearly 100° C.). A mixture of commercial cornstarch and the fat under consideration was then slowly added with continuous stirring, and the heating continued until the starch was well cooked. Skim milk was used to avoid the presence of any considerable amount of butter fat, which would interfere with the study of the particular fat under consideration. The caramel solution was designed to mask the presence of the large quantity of fat by supplying a characteristic and uniform color and flavor to the blanc mange, for a distinctly fatty flavor is disagreeable to many persons and, furthermore, experience has shown that it is highly desirable in making experiments of this character to avoid as far as possible any psychic effects, which in some instances may play an important rôle in the digestion of food. It was usually necessary to add such a large quantity of the caramel solution that the blanc mange had a slightly bitter taste, but this feature was readily overcome by the addition after cooling of a little vanilla extract. The blanc mange prepared in this way resembled a common household dessert, except that it was not noticeably sweet. It has been used to a considerable extent and with good results in this laboratory as a medium for supplying special foodstuffs in experimental diets. The question of the nature of the food was not discussed with the subjects and the masking of the fat was so complete that none of them appeared at any time to notice differences in the flavor of the blanc mange; at least no comments on the matter were made.

In studying the digestibility of a single food, experience has shown that it is desirable to incorporate it in a very simple mixed diet, since the ordinary individual is so accustomed to a mixed diet that, no matter how palatable a single food may be at first, it eventually becomes distasteful. Consequently, in these experiments it was decided to use, in addition to the blanc mange containing the fat under consideration, a very simple mixed basal diet composed of a commercial wheat biscuit, fruit, and tea or coffee, with a little sugar if the subject desired.

¹ It has been noted in the Biochemic Laboratory of the Bureau of Animal Industry that the keeping qualities of fats which have been subjected to elevated temperatures have apparently been lessened.

EXPERIMENTAL METHODS.

Each test period included three days, or nine meals, a period long enough for the purpose, but, as shown by experience, not of sufficient duration to make the diet distasteful. In order that the subject should experience no sense of monotony, the ration in question was served for only one test period per week, followed by a rest period of four days, in which the subject lived as usual on a mixed diet. Furthermore, the tests with fat were alternated with tests of an entirely different sort of diet, so that the same sort of food was not eaten oftener than on alternate weeks.

The subjects changed from time to time according to circumstances, but, since their ages, occupations, and modes of living did not vary materially, the results obtained for the different fats are believed to be directly comparable. The men were between 20 and 30 years of age, students in medical and dental schools, and sufficiently informed in physiological questions to appreciate the importance of accuracy in carrying out such directions as were given them. They were urged to observe special care in the collection of feces, for accuracy in this particular is essential in determining the amount of food retained and assimilated by the body. They were asked to supply data as to their physical condition; both before and after, as well as during the time occupied by the experimental periods, but since all remained in normal physical condition none of the individual reports are incorporated in this paper.

The amounts and kinds of food eaten during each three-day experimental period were recorded as well as the total quantity of feces, and samples of both food and feces were analyzed to determine the quantities of protein, fat, carbohydrate, and mineral matter retained and assimilated by the body. Since sufficient quantities of blanc mange were prepared to serve for an entire test period, only one analysis of the blanc mange was necessary. Only occasional analyses of the wheat biscuit were made, as it was found to be of very uniform composition.

In order to facilitate the identification of the feces of a test period, charcoal,¹ which imparts a dark color to the feces, was taken with the first meal of the test period and with the first meal following the test period. The feces first showing a dark color and all excreted until the color imparted by the charcoal was again noticed were retained for analytical purposes. The feces were freed from water by drying at 95° C., and analysis was made on the dry basis. The urine was not collected and no determinations of the heats of combustion of food or feces were made, since factors have been reported by means of which the available energy value can be computed with

¹ U. S. Dept. Agr., Office Expt. Stas. Bul. 143 (1904), pp. 66-77.

reasonable accuracy. It was not considered necessary to determine variations in the body weight of the subjects, as the purpose of the investigations was to ascertain the availability to the body of the particular fats in question rather than to supply a diet of sufficient nutritive and energy value to meet the body needs. All analytical determinations were made according to the methods outlined by the Association of Official Agricultural Chemists.¹ The resultant data only are included in the report of the experiments which follow. The dates of the individual tests and all the detailed data not essential in interpreting the results are on file at the Department of Agriculture, where they may be consulted.

DIGESTION EXPERIMENTS.

LARD.

Pork fat is utilized for food in a variety of forms, the most common of which are bacon, salt and fresh fat pork, and lard. Lard is used principally for frying and for shortening foods, though sometimes flavored with sweet herbs and spread on bread, like "drippings."

In view of the wide use of lard as a food material, it is noteworthy that no very extensive study of its digestibility has been found on record.

Rubner² determined the digestibility of bacon, making two experiments in which 100 and 200 grams were eaten daily, and found an average digestibility of 87 per cent. This obviously is not a true value, since he reports that the feces contained small pieces of bacon which had not been disintegrated.

Work concerning fat resorption by man and animals in pathological conditions was carried out by Adler.³ His study of pork fat seemed to warrant the conclusion that in pathological conditions cooked bacon was more readily absorbed than raw bacon.

Grindley et al.,⁴ in a study of the influence of different methods of cooking upon the thoroughness and ease of digestion of meat, have reported four experiments with fat fresh pork, the fat of which was 99.4 per cent digested.

In a number of tests comparing the digestibility of lard with that of some other animal fats, Levites⁵ found that lard was somewhat less thoroughly assimilated than butter and beef fat, from which he concluded that lard possesses a laxative property.

Moore,⁶ in conducting experiments to determine the digestibility of some of the more common fats, found that about 97 per cent of

¹ U. S. Dept. Agr., Bur. Chem. Bul. 107 (1912).

² Ztschr. Biol., 15 (1879), No. 1, pp. 170-174.

³ Ztschr. Klin. Med., 66 (1908), No. 3-4, pp. 302-316.

⁴ U. S. Dept. Agr., Office Expt. Stas. Bul. 193 (1907), p. 41.

⁵ Ztschr. Physiol. Chem., 49 (1906), No. 2-3, pp. 273-285.

⁶ Arkansas Sta. Bul. 78 (1903), pp. 33-41.

cooked lard was digested by mice and that raw lard was from 74 to 89 per cent digested by guinea pigs.

To secure data regarding the thoroughness of digestion of lard by normal individuals living under uniform conditions, nine tests were made in this laboratory and six different subjects were used. The experiments were performed in different seasons of the year, because of the belief sometimes expressed that fats are better utilized in colder than in warmer weather. The results are recorded in the following tables:

Data of digestion experiments with lard in a simple mixed diet.

	Weight.	Water.	Protein.	Fat.	Carbo- hydrates.	Ash.
Experiment No. 38, subject J. C.:	<i>Grams.</i>	<i>Grams.</i>	<i>Grams.</i>	<i>Grams.</i>	<i>Grams.</i>	<i>Grams.</i>
Blanc mange containing lard.....	1,765.0	1,086.6	39.9	254.1	375.9	8.5
Wheat biscuit.....	186.5	15.9	25.0	2.1	140.5	3.0
Fruit.....	1,471.5	1,278.7	11.8	2.9	170.7	7.4
Sugar.....	168.0				168.0	
Total food consumed.....	3,591.0	2,381.2	76.7	259.1	855.1	18.9
Feces.....	63.5		17.6	11.2	26.3	8.4
Amount utilized.....			59.1	247.9	828.8	10.5
Per cent utilized.....			77.1	95.7	96.9	55.6
Experiment No. 39, subject J. F.:						
Blanc mange containing lard.....	1,740.5	1,070.3	39.5	250.7	371.4	8.6
Wheat biscuit.....	194.0	16.5	26.0	2.2	146.2	3.1
Fruit.....	1,698.7	1,476.2	13.6	3.4	197.0	8.5
Sugar.....	51.7				51.7	
Total food consumed.....	3,684.9	2,563.0	79.1	256.3	766.3	20.2
Feces.....	86.0		21.1	13.1	41.5	10.3
Amount utilized.....			58.0	243.2	724.9	9.8
Per cent utilized.....			73.3	94.9	94.6	48.5
Experiment No. 44, subject J. C.:						
Blanc mange containing lard.....	1,752.5	947.6	40.1	218.9	532.9	13.0
Wheat biscuit.....	261.0	22.2	35.0	3.0	196.6	4.2
Fruit.....	1,029.5	894.6	8.2	2.1	119.4	5.2
Sugar.....	59.5				59.5	
Total food consumed.....	3,102.5	1,864.4	83.3	224.0	908.4	22.4
Feces.....	64.0		20.0	10.9	25.9	7.2
Amount utilized.....			63.3	213.1	882.5	15.2
Per cent utilized.....			76.0	95.1	97.1	67.9
Experiment No. 47, subject R. L. S.:						
Blanc mange containing lard.....	1,715.6	774.7	40.8	288.4	597.1	14.6
Wheat biscuit.....	493.3	41.9	66.2	5.6	371.7	7.9
Fruit.....	734.7	638.4	5.9	1.5	85.2	3.7
Sugar.....	70.7				70.7	
Total food consumed.....	3,014.3	1,455.0	112.9	295.5	1,124.7	26.2
Feces.....	81.0		25.0	13.8	33.3	8.9
Amount utilized.....			87.9	281.7	1,091.4	17.3
Per cent utilized.....			77.8	95.3	97.0	66.0
Experiment No. 48, subject I. D. B.:						
Blanc mange containing lard.....	1,717.9	777.2	40.8	288.8	596.2	14.9
Wheat biscuit.....	391.8	33.3	52.5	4.5	295.2	6.3
Fruit.....	1,158.6	1,006.8	9.3	2.3	134.4	5.8
Sugar.....	39.3				39.3	
Total food consumed.....	3,307.6	1,817.3	102.6	295.6	1,065.1	27.0
Feces.....	117.8		36.9	24.6	43.1	13.2
Amount utilized.....			65.7	271.0	1,022.0	13.8
Per cent utilized.....			64.0	91.7	96.0	51.1

Data of digestion experiments with lard in a simple mixed diet—Continued.

	Weight.	Water.	Protein.	Fat.	Carbo- hydrates.	Ash.
Experiment No. 53, subject W. D.:	<i>Grams.</i>	<i>Grams.</i>	<i>Grams.</i>	<i>Grams.</i>	<i>Grams.</i>	<i>Grams.</i>
Blanc mange containing lard.....	1,909.1	1,176.0	56.1	263.6	399.8	13.5
Wheat biscuit.....	418.3	35.6	56.1	4.8	315.2	6.7
Fruit.....	1,362.2	1,183.8	10.9	2.7	158.0	6.8
Sugar.....						
Total food consumed.....	3,689.6	2,395.4	123.1	271.1	873.0	27.0
Feces.....	92.4		19.9	15.8	44.9	11.8
Amount utilized.....			103.2	255.3	828.1	15.1
Per cent utilized.....			83.8	94.2	94.9	55.9
Experiment No. 54, subject I. D. B.:						
Blanc mange containing lard.....	1,924.1	1,185.2	56.6	265.7	402.9	13.7
Wheat biscuit.....	578.1	49.1	77.5	6.6	435.6	9.3
Fruit.....	1,245.2	1,082.1	10.0	2.5	144.4	6.2
Sugar.....	97.3				97.3	
Total food consumed.....	3,844.7	2,316.4	144.1	274.8	1,080.2	29.2
Feces.....	159.2		48.1	32.3	63.9	14.9
Amount utilized.....			96.0	242.5	1,016.3	14.3
Per cent utilized.....			66.6	88.2	94.0	49.0
Experiment No. 55, subject R. L. S.:						
Blanc mange containing lard.....	2,118.8	1,305.2	62.3	292.6	443.7	15.0
Wheat biscuit.....	637.1	54.2	85.4	7.3	480.0	10.2
Fruit.....	742.3	645.0	6.0	1.5	86.1	3.7
Sugar.....	54.0				54.0	
Total food consumed.....	3,552.2	2,004.4	153.7	301.4	1,063.8	28.9
Feces.....	87.7		24.3	18.0	36.1	9.3
Amount utilized.....			129.4	283.4	1,027.7	19.6
Per cent utilized.....			84.2	94.0	96.6	67.8
Experiment No. 56, subject E. M.:						
Blanc mange containing lard.....	1,808.1	1,113.8	53.2	249.7	378.6	12.8
Wheat biscuit.....	465.0	39.5	62.4	5.3	350.4	7.4
Fruit.....	1,496.6	1,300.5	12.0	3.0	173.6	7.5
Sugar.....	110.3				110.3	
Total food consumed.....	3,880.0	2,453.8	127.6	258.0	1,012.9	27.7
Feces.....	110.1		35.7	13.9	46.7	13.8
Amount utilized.....			91.7	244.1	966.2	13.9
Per cent utilized.....			72.0	94.6	95.4	50.2
Average food consumed per subject per day	1,172.8	713.0	37.2	90.2	324.1	8.4

Summary of digestion experiments with lard in a simple mixed diet.

Experi- ment No.	Subject.	Protein.	Fat.	Carbohy- drates.	Ash.
		<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>
38	J. C.....	77.1	95.7	96.9	55.6
39	J. F.....	73.3	94.9	94.6	48.5
44	J. C.....	76.0	95.1	97.1	67.9
47	R. L. S.....	77.8	95.3	97.0	66.0
48	I. D. B.....	64.0	91.7	96.0	51.1
53	W. D.....	83.8	94.2	94.9	55.9
54	I. D. B.....	66.6	88.2	94.0	49.0
55	R. L. S.....	84.2	94.0	96.6	67.8
56	E. M.....	72.0	94.6	95.4	50.2
	Average.....	75.0	93.7	95.8	56.9

It will be noted on reference to the table that in experiments Nos. 48 and 54, both with the same subject (I. D. B.), the percentage digestibility of fat is materially lower than the others and that this

tends to lower the average. However, since there were apparently no abnormal conditions, these results have been included in obtaining the average. The digestibility of the fat content of the total diet, 93.7 per cent, should closely approximate the digestibility of lard, since over 97 per cent of the total fat consumed was lard.

The "digestibility" of fat is often a matter of popular discussion, and not infrequently the statement is made that "lard is indigestible." The term "indigestible" in the accurate sense implies that a large part of the food in question leaves the body unassimilated, though sometimes the expression is loosely used to explain a digestive disturbance resulting from eating the food. In these tests the fat was very thoroughly assimilated as compared with the other fats included in the investigation, so it was not indigestible in the sense that it failed to digest. No distress was experienced by the subjects, nor were any unusual circumstances observed, so in these experiments at least, the lard was not "indigestible" in the popular sense.

It is frequently noted that those who think they can not eat lard have no such feeling in regard to bacon, which is one of the very popular fat foods. Before the whole question can be settled, it is desirable to make tests with lard, bacon, and other fats, in which the fat is incorporated with the other ingredients of the diet of which it forms a part and subjected to a higher temperature (as in frying and baking) than was used to make the blanc mange in these experiments.

BEEF FAT.

Beef suet is used as a fat for sautéing and deep frying and in making suet puddings and dumplings, which are fairly common in the United States, though less so than in Great Britain, and for other culinary purposes. Rendered beef fat is not used as a table fat in this country to any great extent, though in Europe families of small means often eat so-called "drippings" on their bread in the place of butter.

Beef suet has a rather pronounced and characteristic flavor as well as a comparatively high melting point; to these properties may be attributed the fact that it is not a common table fat in the United States. Experience and experiments show that it is possible to remove much of the characteristic taste. One household method which is fairly successful is to mix milk with the suet when it is rendered, using half a cup of milk to a pound of suet. On straining and cooling practically all the milk solids are occluded and serve to change or mask the characteristic beef-fat flavor.

As was the case with lard, few reports of experiments on the digestibility of beef fat have been found.

Flurin¹ was interested in determining the relative digestibility of butter and beef tallow, which he regarded as typical animal fats. The average coefficients of digestibility were found to be 95.9 per cent and 92.8 per cent, respectively.

Levites² studied the relative digestibility of beef fat, lard, and butter, and found that butter and beef fat were both 96 per cent digested.

Grindley et al.,² in experiments to determine the thoroughness of digestion of various meats, found that the average digestibility of fat present in a shoulder of beef rich in fat was 97.3 per cent, but this coefficient may not be applicable to kidney fat. In an attempt to compare the digestibility of edible fats, using guinea pigs as subjects, Moore² found that the fat of raw beef suet was 73.7 per cent utilized.

In the work here reported the fat was incorporated in a blanc mange in the manner previously described. During the first three experiments the subjects ate large amounts, approximately 140 grams per day, but they reported a laxative effect from eating this quantity of fat. As this seemed to indicate that the limit of tolerance was being approached, smaller quantities of fat were eaten in the succeeding periods.

The results of the digestion experiments with beef fat contained in a simple mixed diet follow:

Data of digestion experiments with beef fat in a simple mixed diet.

	Weight.	Water.	Protein.	Fat.	Carbo- hydrates.	Ash.
	Grams.	Grams.	Grams.	Grams.	Grams	Grams.
Experiment No. 61, subject W. D.:						
Blanc mange containing beef fat.....	2,255.5	1,134.5	45.1	412.8	649.6	13.5
Wheat biscuit.....	544.9	46.3	73.0	6.0	410.9	8.7
Fruit.....	1,354.0	1,176.6	10.8	2.7	157.1	6.8
Sugar.....						
Total food consumed.....	4,154.4	2,357.4	128.9	421.5	1,217.6	29.0
Feces.....	80.5		17.5	23.8	31.2	8.0
Amount utilized.....			111.4	397.7	1,186.4	21.0
Per cent utilized.....			86.4	94.4	97.4	72.4
Experiment No. 62, subject E. M.:						
Blanc mange containing beef fat.....	2,486.0	1,250.5	49.7	454.9	716.0	14.9
Wheat biscuit.....	499.8	42.5	67.0	5.5	376.8	8.0
Fruit.....	1,220.3	1,060.4	9.8	2.4	141.6	6.1
Sugar.....	110.2				110.2	
Total food consumed.....	4,316.3	2,353.4	126.5	462.8	1,344.6	29.0
Feces.....	102.9		26.9	28.8	36.8	10.4
Amount utilized.....			99.6	434.0	1,307.8	18.6
Per cent utilized.....			78.7	93.8	97.3	64.1
Experiment No. 63, subject R. L. S.:						
Blanc mange containing beef fat.....	2,141.4	1,077.1	42.8	391.9	616.7	12.9
Wheat biscuit.....	533.7	45.4	71.5	5.9	402.4	8.6
Fruit.....	1,250.2	1,086.4	10.0	2.5	145.0	6.3
Sugar.....	69.0				69.0	
Total food consumed.....	3,994.3	2,208.9	124.3	400.3	1,233.1	27.8
Feces.....	116.1		28.7	44.2	32.4	10.9
Amount utilized.....			95.6	356.1	1,200.7	16.9
Per cent utilized.....			76.9	89.0	97.4	60.8

¹ Diss., Army Med. Acad. St. Petersburg, 1890, p. 52.

² Loc. cit.

Data of digestion experiments with beef fat in a simple mixed diet—Continued.

	Weight.	Water.	Protein.	Fat.	Carbo- hydrates.	Ash.
	<i>Grams.</i>	<i>Grams.</i>	<i>Grams.</i>	<i>Grams.</i>	<i>Grams.</i>	<i>Grams.</i>
Experiment No. 69, subject R. L. S.:						
Blanc mange containing beef fat.....	2,265.1	1,229.5	39.4	267.5	719.4	9.3
Wheat biscuit.....	661.1	56.2	88.6	7.3	498.5	10.5
Fruit.....	1,131.0	982.8	9.1	2.3	131.2	5.6
Sugar.....	77.3				77.3	
Total food consumed.....	4,134.5	2,268.5	137.1	277.1	1,426.4	25.4
Feces.....	137.0		35.1	39.9	49.3	12.7
Amount utilized.....			102.0	237.2	1,377.1	12.7
Per cent utilized.....			74.4	85.6	96.5	50.0
Experiment No. 70, subject I. D. B.:						
Blanc mange containing beef fat.....	2,275.2	1,235.0	39.6	268.7	722.6	9.3
Wheat biscuit.....	447.6	38.0	60.0	4.9	337.5	7.2
Fruit.....	1,229.0	1,068.0	9.8	2.5	142.6	6.1
Sugar.....	60.2				60.2	
Total food consumed.....	4,012.0	2,341.0	109.4	276.1	1,262.9	22.6
Feces.....	145.1		41.1	33.9	57.7	12.4
Amount utilized.....			68.3	242.2	1,205.2	10.2
Per cent utilized.....			62.4	87.7	95.4	45.1
Experiment No. 71, subject W. D.:						
Blanc mange containing beef fat.....	2,274.4	1,234.5	39.6	268.6	722.4	9.3
Wheat biscuit.....	495.5	42.1	66.4	5.5	373.6	7.9
Fruit.....	1,381.1	1,200.2	11.0	2.8	160.2	6.9
Sugar.....						
Total food consumed.....	4,151.0	2,476.8	117.0	276.9	1,256.2	24.1
Feces.....	91.5		21.5	24.4	35.9	9.7
Amount utilized.....			95.5	252.5	1,220.3	14.4
Per cent utilized.....			81.6	91.2	97.1	59.8
Experiment No. 72, subject E. M.:						
Blanc mange containing beef fat.....	2,462.4	1,336.6	42.8	290.8	782.1	10.1
Wheat biscuit.....	553.5	47.0	74.2	6.1	417.3	8.9
Fruit.....	1,528.6	1,328.4	12.2	3.1	177.3	7.6
Sugar.....	121.6				121.6	
Total food consumed.....	4,666.1	2,712.0	129.2	300.0	1,498.3	26.6
Feces.....	123.8		31.6	29.0	51.7	11.5
Amount utilized.....			97.6	271.0	1,446.6	15.1
Per cent utilized.....			75.5	90.3	96.5	56.8
Experiment No. 102, subject I. D. B.:						
Blanc mange containing beef fat.....	2,200.8	1,151.3	39.8	206.0	793.8	9.9
Wheat biscuit.....	557.7	47.4	74.8	6.1	420.5	8.9
Fruit.....	1,642.4	1,427.3	13.1	3.3	190.5	8.2
Sugar.....	44.4				44.4	
Total food consumed.....	4,445.3	2,626.0	127.7	215.4	1,449.2	27.0
Feces.....	109.9		26.6	27.4	45.5	10.4
Amount utilized.....			101.1	188.0	1,403.7	16.6
Per cent utilized.....			79.2	87.3	96.9	61.5
Experiment No. 103, subject W. D.:						
Blanc mange containing beef fat.....	1,145.0	598.9	20.7	107.2	413.0	5.2
Wheat biscuit.....	257.9	21.9	34.6	2.8	194.5	4.1
Fruit.....	1,331.2	1,156.8	10.6	2.7	154.4	6.7
Sugar.....	18.0				18.0	
Total food consumed.....	2,752.1	1,777.6	65.9	112.7	779.9	16.0
Feces.....	84.3		20.4	19.8	34.3	9.8
Amount utilized.....			45.5	92.9	745.6	6.2
Per cent utilized.....			69.0	82.4	95.6	38.8
Experiment No. 104, subject E. M.:						
Blanc mange containing beef fat.....	2,510.0	1,313.0	45.4	234.9	905.4	11.3
Wheat biscuit.....	328.9	28.0	44.0	3.6	248.0	5.3
Fruit.....	1,417.5	1,231.8	11.4	2.8	164.4	7.1
Sugar.....	156.2				156.2	
Total food consumed.....	4,412.6	2,572.8	100.8	241.3	1,474.0	23.7
Feces.....	114.2		28.5	30.2	44.2	11.3
Amount utilized.....			72.3	211.1	1,429.8	12.4
Per cent utilized.....			71.7	87.5	97.0	52.3
Average food consumed per subject per day.....	1,368.0	789.8	38.9	99.5	431.4	8.4

Summary of digestion experiments with beef fat in a simple mixed diet.

Experiment No.	Subject.	Protein.	Fat.	Carbohydrates.	Ash.
		<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>
61	W. D.....	86.4	94.4	97.4	72.4
62	E. M.....	78.7	93.8	97.3	64.2
63	R. L. S.....	76.9	89.0	97.4	60.8
69	R. L. S.....	74.4	85.6	96.5	50.0
70	I. D. B.....	62.4	87.7	95.4	45.1
71	W. D.....	81.6	91.2	97.1	59.8
72	E. M.....	75.5	90.3	96.5	56.8
102	I. D. B.....	79.2	87.3	96.9	61.5
103	W. D.....	69.0	82.4	95.6	38.8
104	E. M.....	71.7	87.5	97.0	52.3
	Average.....	75.6	88.9	96.7	56.2

The average value, 88.9 per cent, is the digestibility of the fat content of the entire ration. However, this, it is believed, may be taken to represent the coefficient of digestibility of beef fat alone, inasmuch as this fat comprised over 97 per cent of the total fat content of the diet. The digestibility seemed to decrease with the decrease in the amount of fat consumed. One reason may be that the ether extract of the feces contains not only the undigested fat, but also some ether-soluble metabolic products. If it be assumed that the amount of metabolic products remained fairly constant in the different tests, there would obviously be a proportionately larger quantity present in the feces as the amount of fat consumed decreased.

MUTTON FAT.

That only small quantities of mutton fat are used in the United States for culinary purposes may be due partly to a smaller available supply, partly to its marked flavor, and partly to its relatively high melting point and corresponding hardness. The possibility of extending its use was considered in work undertaken with reference to the use of mutton in the diet.¹ One method of utilizing mutton fat in cooking consists in mixing small quantities after rendering with softer fats, such as lard. The resulting mixture is somewhat softer than the mutton fat and may be used for various household purposes. It is possible to make a savory fat by heating the mutton fat at a low temperature with an onion or sour apple and a little summer savory or ground thyme until the onion or apple is thoroughly brown. The peculiar flavor seems to be masked by this process, the savoriness being quite likely due to a solution in the fat of specific flavoring bodies in the seasoning herb and the browned fruit and vegetable.

Very little experimental work concerning the digestibility of mutton fat has been found. Grindley² in his studies of the effect of cooking upon the digestibility of meats included among others a leg of mut-

¹ U. S. Dept. Agr., Farmers' Bul. 526 (1913).² Loc. cit.

ton, and found that the average digestibility of the fat in the ration was 98.5 per cent. His investigation was carried out, however, under conditions very different from those herein reported, as he included in the basal ration large amounts of meat.

A total of seven tests, each of three days' duration, was made with a diet containing a large quantity of mutton fat, and conditions parallel to those of the previous work were maintained throughout the experimental periods. The results are given below:

Data of digestion experiments with mutton fat in a simple mixed diet.

	Weight.	Water.	Protein.	Fat.	Carbohy- drates.	Ash.
Experiment No. 93, subject R. L. S.:	<i>Grams.</i>	<i>Grams.</i>	<i>Grams.</i>	<i>Grams.</i>	<i>Grams.</i>	<i>Grams.</i>
Blanc mange containing mutton fat...	1,581.2	798.0	26.7	120.7	628.7	7.1
Wheat biscuit.....	467.1	39.7	62.6	5.1	352.2	7.5
Fruit.....	635.5	552.2	5.1	1.3	73.7	3.2
Sugar.....	49.2				49.2	
Total food consumed.....	2,733.0	1,389.9	94.4	127.1	1,403.8	17.8
Feces.....	100.7		24.4	34.2	32.8	9.2
Amount utilized.....			70.0	92.8	1,071.0	8.5
Per cent utilized.....			74.1	73.0	97.0	48.0
Experiment No. 94, subject I. D. B.:						
Blanc mange containing mutton fat...	1,895.6	956.7	32.0	144.6	753.7	8.6
Wheat biscuit.....	592.4	50.3	79.4	6.5	446.7	9.5
Fruit.....	1,397.0	1,214.0	11.2	2.8	162.0	7.0
Sugar.....	80.2				80.2	
Total food consumed.....	3,965.2	2,221.0	122.6	153.9	1,442.6	25.1
Feces.....	108.8		27.5	29.8	42.0	9.4
Amount utilized.....			95.1	124.1	1,400.6	15.7
Per cent utilized.....			77.5	80.6	97.1	62.5
Experiment No. 95, subject W. D.:						
Blanc mange containing mutton fat...	960.7	484.9	16.2	73.3	382.0	4.3
Wheat biscuit.....	262.0	22.3	35.1	2.9	197.5	4.2
Fruit.....	1,363.5	1,184.9	10.9	2.7	158.2	6.8
Sugar.....	32.3				32.3	
Total food consumed.....	2,618.5	1,692.1	62.2	78.9	770.0	15.3
Feces.....	79.6		18.7	21.7	30.1	9.0
Amount utilized.....			43.5	57.2	739.9	6.3
Per cent utilized.....			69.9	72.4	96.1	41.2
Experiment No. 96, subject E. M.:						
Blanc mange containing mutton fat...	2,360.8	1,191.5	39.9	180.1	938.7	10.6
Wheat biscuit.....	366.4	31.1	49.1	4.0	276.3	5.9
Fruit.....	1,482.3	1,288.1	11.9	3.0	171.9	7.4
Sugar.....	82.2				82.2	
Total food consumed.....	4,291.7	2,510.7	100.9	187.1	1,469.1	23.9
Feces.....	132.6		35.4	33.7	51.0	12.5
Amount utilized.....			65.5	153.4	1,418.1	11.4
Per cent utilized.....			64.9	82.0	96.5	47.7
Experiment No. 131, subject D. G. G.:						
Blanc mange containing mutton fat...	1,508.0	697.3	29.2	218.1	556.9	6.5
Wheat biscuit.....	765.0	65.0	102.5	8.4	576.8	12.3
Fruit.....	1,042.0	905.5	8.3	2.1	120.9	5.2
Sugar.....	122.0				122.0	
Total food consumed.....	3,437.0	1,667.8	140.0	228.6	1,376.6	24.0
Feces.....	122.6		32.0	26.9	52.0	11.7
Amount utilized.....			108.0	201.7	1,324.6	12.3
Per cent utilized.....			77.1	88.2	96.2	51.2

Data of digestion experiments with mutton fat in a simple mixed diet—Continued.

	Weight.	Water.	Protein.	Fat.	Carbohy- drates.	Ash.
Experiment No. 132, subject H. D. G.:	<i>Grams.</i>	<i>Grams.</i>	<i>Grams.</i>	<i>Grams.</i>	<i>Grams.</i>	<i>Grams.</i>
Blanc mange containing mutton fat	769.0	355.6	14.9	111.2	284.0	3.3
Wheat biscuit	483.0	41.1	64.7	5.3	364.2	7.7
Fruit	1,504.0	1,307.0	12.0	3.0	174.5	7.5
Sugar	183.0				183.0	
Total food consumed	2,939.0	1,703.7	91.6	119.5	1,005.7	18.5
Feces	84.5		22.6	19.2	33.8	9.0
Amount utilized			69.0	100.3	971.9	9.5
Per cent utilized			75.3	83.9	96.6	51.5
Experiment No. 133, subject R. L. S.:						
Blanc mange containing mutton fat	1,472.0	680.6	28.6	212.9	543.6	6.3
Wheat biscuit	552.0	46.9	4.0	6.1	416.2	8.8
Fruit	1,360.0	1,181.8	10.9	2.7	157.8	6.8
Sugar	63.0				63.0	
Total food consumed	3,447.0	1,909.3	113.5	221.7	1,180.6	21.9
Feces	110.5		28.7	36.7	32.3	12.8
Amount utilized			84.8	185.0	1,148.3	9.1
Per cent utilized			74.7	83.4	97.3	41.6
Average food consumed per subject per day	1,115.8	623.6	34.5	53.2	397.5	7.0

Summary of digestion experiments with mutton fat in a simple mixed diet.

Experi- ment No.	Subject.	Protein.	Fat.	Carbohy- drates.	Ash.
		<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>
93	R. L. S.	74.1	73.0	97.0	48.0
94	I. D. B.	77.5	80.6	97.1	62.5
95	W. D.	69.9	72.4	96.1	41.2
96	E. M.	64.9	82.0	96.5	47.7
131	D. G. G.	77.1	88.2	96.2	51.2
132	H. D. G.	75.3	83.9	96.6	51.5
133	R. L. S.	74.7	83.4	97.3	41.6
	Average	73.4	80.5	96.7	49.1

The above data show that relatively small amounts of mutton fat were consumed, which was probably due for the most part to the pronounced flavor and to the well-known fact that mutton fat makes the mouth feel "furry," for it cools in the mouth and clings to the skin. This clinging effect is not noticeable with fats which remain fluid in the mouth.

The low values for availability of fat obtained in experiments Nos. 93 (R. L. S.) and 95 (W. D.), have lowered the general average. The digestibility of mutton fat would be increased to 83.6 per cent by disregarding these values; but, since the values for the digestibility of the protein and carbohydrate approximate the average, the evidence is thought insufficient to warrant such a correction. The average digestibility of mutton fat, therefore, is given as 80.5 per cent. This is materially lower than that of any of the other animal fats studied, though it is apparent that in comparison with many common foods the fat is sufficiently well assimilated to serve satisfactorily as a food material.

BUTTER.

Many investigators have studied the digestibility of butter under a wide variety of conditions, because of its very extensive use in countries where it is obtainable at relatively low prices. In a number of the earlier determinations the rations used consisted of only one food material in addition to the butter.

Rubner,¹ as a part of an extended series of experiments, determined the digestibility of a simple ration of butter and potatoes, and of one made up of green beans (540.2 grams) and butter (53.4 grams).² The coefficient of digestibility of fat in the first case was 96.3 per cent and in the second 91.5 per cent. In another test,³ with a ration containing a considerably larger proportion of fat—240 grams of butter—daily, this fat was 97.3 per cent assimilated.

Atwater,⁴ in studies made previous to his connection with the nutrition investigations of the Department of Agriculture, studied a simple diet of fish (1,584 grams) and butter (30.5 grams), and found that the fat had a coefficient of digestibility of 91 per cent.

A similar experiment by Malfatti⁵ is reported in which polenta (a porridge made of Indian corn meal and butter), supplying 92.5 grams of fat per day, was used. The coefficient of digestibility of the fat of the corn meal alone was found to be 57.86 per cent, while the butter, which supplied by far the greater part of the fat content of the ration, was 97.7 per cent available.

The variation in digestibility as determined by the different investigators is doubtless due to a lack of uniformity of conditions under which the experiments were performed. The results of these early experiments, however, agree fairly well in showing that butter is very completely digested. In later experiments, which are also of interest, a more complex basal ration seems to have been used.

Mayer⁶ studied the thoroughness of the digestion of butter by a 39-year-old man and a 9-year-old boy, who were given butter in a simple mixed diet. The average digestibility of butter as determined by three experimental periods, each of three days' duration, was for the man 98 per cent and for the boy 97 per cent.

Bertarelli⁷ investigated the nutritive value of butter, using three healthy men as subjects for one experimental period each. He obtained 94 per cent as an average digestibility.

Huldgren and Landergren⁸ used a simple basal ration of rye bread made of rye flour, water, and yeast and baked in hard, thin cakes.

¹ Ztschr. Biol., 15 (1879), No. 1, pp. 136-147.

² Idem, 16 (1880), No. 1, p. 127.

³ Idem, 15 (1879), No. 1, pp. 174-176.

⁴ Idem, 24 (1887), No. 1, p. 16.

⁵ Sitzber. K. Akad. Wiss. [Vienna], Math. Naturw. Kl., 90 (1884), III, No. 5, pp. 328-335.

⁶ Landw. Vers. Stat., 29 (1883), pp. 215-232.

⁷ Riv. Ig. e. Sanit. Pub., 9 (1898), Nos. 14, pp. 538-545; 15, pp. 570-579.

⁸ Skand. Arch. Physiol., 2 (1890), No. 4-5, pp. 373-393.

The experimenters themselves were the subjects, and found that 95.43 per cent of butter fat was digested.

Lühlig¹ found that butter in a basal ration of meat, bread, and vegetables was 96 per cent digested by a healthy man 29 years old. In a later paper² he reports a digestibility of 97 per cent.

Another series of experiments in which the experimenters were subjects was conducted by Wibbens and Huizenga,³ who compared butter and sana (a butter substitute which contained no milk fat). A simple mixed diet was eaten during periods of three days' duration. For one subject the fat digestibilities were: Butter, 97.33 per cent; sana, 95.3 per cent; for the other subject, butter, 96.5; sana, 73.79 per cent.

A much longer experimental period, one of 28 days' duration, divided into a fore period of 7 days, a period of 14 days on the special diet studied, and an after period of 7 days, was preferred by Von Gerlach.⁴ He determined the thoroughness of digestion of butter and of a commercial product called "sanella" (of vegetable origin), when the basal ration consisted of rice, zweiback, and oatmeal. Both fats were 97 per cent digested.

Flurin⁵ and Levites⁵ have found that butter was 96 per cent assimilated.

Investigating the digestibility of the protein, fat, and carbohydrate contents of the ordinary mixed diet, Atwater⁶ used varying amounts of butter (40 grams to 343 grams per man per day) in the ration, and concluded that for three different subjects in 21 experiments the fat of the diet was 95.9 per cent available to the body.

It is difficult to compare the results of all these investigations, since the experimental conditions were not of similar nature. In the main, however, they show that butter fat is very well assimilated.

In the eight tests recently conducted in this laboratory conditions were more nearly uniform, as the butter was added to the same simple mixed diet and eaten by the same subjects who participated in the other experiments. The results which were obtained follow.

¹ Ztschr. Untersuch. Nahr. u. Genussmtl., 2 (1899), No. 6, pp. 484-506.

² Idem, No. 10, pp. 769-783.

³ Pflüger's Arch. Physiol., 83 (1901), No. 10-12, pp. 609-618.

⁴ Ztschr. Phys. u. Diätet: Ther., 12 (1908-9), No. 2, pp. 102-110.

⁵ Loc. cit.

⁶ Connecticut Storrs Sta. Rpt. 1901, p. 235.

Data of digestion experiments with butter in a simple mixed diet.

	Weight.	Water.	Protein.	Fat.	Carbo- hydrates.	Ash.
Experiment No. 85, subject R. L. S.:	<i>Grams.</i>	<i>Grams.</i>	<i>Grams.</i>	<i>Grams.</i>	<i>Grams.</i>	<i>Grams.</i>
Blanc mange containing butter.....	1,707.0	757.7	28.9	314.9	585.2	20.3
Wheat biscuit.....	403.8	34.3	54.1	4.4	304.5	6.5
Fruit.....	909.9	790.7	7.3	1.8	105.6	4.5
Sugar.....	51.0				51.0	
Total food consumed.....	3,071.7	1,582.7	90.3	321.1	1,046.3	31.3
Feces.....	73.9		19.6	22.6	24.2	7.5
Amount utilized.....			70.7	298.5	1,022.1	23.8
Per cent utilized.....			78.3	93.0	97.7	76.0
Experiment No. 86, subject I. D. B.:						
Blanc mange containing butter.....	1,911.7	848.6	32.3	352.7	655.3	22.8
Wheat biscuit.....	398.6	33.9	53.4	4.4	300.5	6.4
Fruit.....	1,122.0	975.0	9.0	2.2	130.2	5.6
Sugar.....	84.0				84.0	
Total food consumed.....	3,516.3	1,857.5	94.7	359.3	1,170.0	34.8
Feces.....	114.9		34.8	16.8	51.9	11.4
Amount utilized.....			59.9	342.5	1,118.1	23.4
Per cent utilized.....			63.3	95.3	95.6	67.2
Experiment No. 87, subject W. D.:						
Blanc mange containing butter.....	1,008.5	447.7	17.0	186.1	345.7	12.0
Wheat biscuit.....	340.5	28.9	45.8	3.7	256.7	5.4
Fruit.....	1,201.6	1,044.2	9.6	2.4	139.4	6.0
Sugar.....						
Total food consumed.....	2,550.6	1,520.8	72.4	192.2	741.8	23.4
Feces.....	83.2		21.7	16.9	34.9	9.7
Amount utilized.....			50.7	175.3	706.9	13.7
Per cent utilized.....			70.0	91.2	95.3	58.5
Experiment No. 88, subject E. M.:						
Blanc mange containing butter.....	2,067.3	917.7	34.9	381.4	708.7	24.6
Wheat biscuit.....	329.7	28.0	44.2	3.6	248.6	5.3
Fruit.....	1,214.2	1,055.1	9.7	2.4	140.8	6.1
Sugar.....	94.9				94.9	
Total food consumed.....	3,706.1	2,000.8	88.8	387.4	1,193.0	36.0
Feces.....	96.7		29.9	14.3	42.5	10.1
Amount utilized.....			58.9	373.1	1,150.5	25.9
Per cent utilized.....			66.3	96.3	96.4	71.9
Experiment No. 117, subject R. L. S.:						
Blanc mange containing butter.....	1,234.0	574.9	20.9	195.8	428.1	14.3
Wheat biscuit.....	485.0	41.2	5.0	5.3	365.7	7.8
Fruit.....	794.0	670.0	6.3	1.6	92.1	4.0
Sugar.....	44.0				44.0	
Total food consumed.....	2,557.0	1,306.1	92.2	202.7	929.9	26.1
Feces.....	94.7		30.5	18.5	33.0	12.7
Amount utilized.....			61.7	184.2	896.9	13.4
Per cent utilized.....			66.9	90.9	96.5	51.3
Experiment No. 118, subject I. D. B.:						
Blanc mange containing butter.....	2,017.0	939.7	34.1	320.1	699.7	23.4
Wheat biscuit.....	497.0	42.2	66.6	5.5	374.7	8.0
Fruit.....	948.0	823.8	7.6	1.9	110.0	4.7
Sugar.....	92.0				92.0	
Total food consumed.....	3,554.0	1,805.7	108.3	327.5	1,276.4	36.1
Feces.....	103.7		27.9	17.4	47.8	10.5
Amount utilized.....			80.4	310.1	1,228.6	25.6
Per cent utilized.....			74.2	94.7	96.3	70.9
Experiment No. 119, subject W. D.:						
Blanc mange containing butter.....	1,501.0	699.3	25.4	238.2	520.7	17.4
Wheat biscuit.....	354.0	30.1	47.4	3.9	266.9	5.7
Fruit.....	1,143.0	993.3	9.1	2.3	132.6	5.7
Sugar.....						
Total food consumed.....	2,998.0	1,722.7	81.9	244.4	920.2	28.8
Feces.....	96.0		21.9	15.3	35.0	13.8
Amount utilized.....			60.0	229.1	885.2	15.0
Per cent utilized.....			73.3	93.7	96.2	52.1

Data of digestion experiments with butter in a simple mixed diet—Continued.

	Weight.	Water.	Protein.	Fat.	Carbo- hydrates.	Ash.
Experiment No. 120, subject E. M.:	<i>Grams.</i>	<i>Grams.</i>	<i>Grams.</i>	<i>Grams.</i>	<i>Grams.</i>	<i>Grams.</i>
Blanc mange containing butter.....	2,198.0	1,024.0	37.2	348.8	762.5	25.5
Wheat biscuit.....	294.0	25.0	39.4	3.2	221.7	4.7
Fruit.....	1,194.0	1,037.6	9.5	2.4	138.5	6.0
Sugar.....	105.0				105.0	
Total food consumed.....	3,791.0	2,086.6	86.1	354.4	1,227.7	36.2
Feces.....	84.2		24.1	15.2	34.8	10.2
Amount utilized.....			62.0	339.2	1,192.9	26.0
Per cent utilized.....			72.0	95.7	97.2	71.9
Average food consumed per subject per day.	1,072.7	578.7	29.8	99.5	354.4	10.5

Summary of digestion experiments with butter in a simple mixed diet.

Experi- ment No.	Subject.	Protein.	Fat.	Carbo- hydrates.	Ash.
		<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>
85	R. L. S.....	78.3	93.0	97.7	76.0
86	I. D. B.....	63.3	95.3	95.6	67.2
87	W. D.....	70.0	91.2	95.3	58.5
88	E. M.....	66.3	96.3	96.4	71.9
117	R. L. S.....	66.9	90.9	96.5	51.3
118	I. D. B.....	74.2	94.7	96.3	70.9
119	W. D.....	73.3	93.7	96.2	52.1
120	E. M.....	72.0	95.7	97.2	71.9
	Average.....	70.5	93.9	96.4	65.0

Having an average digestibility of 93.9 per cent, butter fat may be considered more completely assimilated than any of the other animal fats considered in this report. Though a reasonable allowance of butter is 3 ounces, or 85 grams, per man per day, the experiments as a whole emphasize a fact of common experience, namely, that somewhat larger quantities of butter (100 grams per day at least) may be eaten in ordinary circumstances and utilized without any noticeable physiological disturbance.

ALLOWANCE FOR METABOLIC FAT.

The coefficients of digestibility given in the preceding discussion are gross rather than net values. They have been derived in the customary way by analyzing the food eaten and the feces excreted during an experimental period to determine especially what proportion of the ingested fat was available for the maintenance of the needs of the body. For this purpose the total ether extract of the feces has been taken to represent the actual quantity of undigested fat—the unavailable residual of the fat eaten during the experimental period. That this assumption is not strictly true is apparent from a study of the composition of the feces. It is well known that the feces contain not only undigested residues of food, but certain other waste materials,

which are ordinarily designated as metabolic products. These include residues of bacteria, digestive juices, internal secretions, and epithelial cells of the stomach and intestines. Some of these products of the body metabolism are soluble in ether and therefore occur in the ether extract of the feces, together with the fat actually unavailable. Moreover, these metabolic products are not derived necessarily from the fat under consideration, but may be formed from protein and carbohydrate as well, and probably are produced partly from food eaten prior to the beginning of the experimental period.

To determine either the amount or the percentage of fat actually unutilized as distinguished from the total fecal fat (often called "undigested fat"), allowance must be made for fat in the fecal metabolic products. The method adopted is not a direct one, since it is impractical to make the separation quantitatively, but is based on the assumption that the quantity and quality of metabolic products found depend on the nature and the amount of ingested food—that the average percentage of metabolic products found in the ether extract when the basal ration alone is eaten will be approximately equal to that when the basal ration together with added fat is consumed.

Four experiments are herein reported with the basal ration without added fat. The procedure was in no way different from that employed in those tests in which large amounts of added fat were eaten, the bulk of food in each series of experiments being approximately equal. The results of these tests are given below and furnish a basis for calculating the necessary allowance for the metabolic products contained in the ether extract of the feces.

Data of digestion experiments with basal ration.

	Weight.	Water.	Protein.	Fat.	Carbo- hydrates.	Ash.
	Grams.	Grams.	Grams.	Grams.	Grams.	Grams.
Experiment No. 266, subject H. F. B.:						
Blanc mange without added fat.....	2,307.0	1,296.8	45.4	14.5	939.0	11.3
Wheat biscuit.....	592.0	47.4	65.1	17.8	449.9	11.8
Fruit.....	1,392.0	1,211.0	13.9		167.1	
Sugar.....	208.0				208.0	
Total food consumed.....	4,499.0	2,555.2	124.4	32.3	1,764.0	23.1
Feces.....	136.0		33.9	11.8	73.4	11.9
Amount utilized.....			85.5	20.5	1,690.6	11.2
Per cent utilized.....			68.7	63.5	95.8	48.5
Experiment No. 267, subject D. G. G.:						
Blanc mange without added fat.....	1,922.0	1,080.4	37.9	12.1	782.2	9.4
Wheat biscuit.....	335.0	26.8	36.9	10.0	254.6	6.7
Fruit.....	1,027.0	893.5	10.3		123.2	
Sugar.....	149.0				149.0	
Total food consumed.....	3,433.0	2,000.7	85.1	22.1	1,309.0	16.1
Feces.....	87.0		28.6	8.3	42.2	7.9
Amount utilized.....			56.5	13.8	1,266.8	8.2
Per cent utilized.....			66.4	62.4	96.8	50.9

Data of digestion experiments with basal ration—Continued.

	Weight.	Water.	Protein.	Fat.	Carbo- hydrates.	Ash.
Experiment No. 268, subject R. L. S.:	<i>Grams.</i>	<i>Grams.</i>	<i>Grams.</i>	<i>Grams.</i>	<i>Grams.</i>	<i>Grams.</i>
Blanc mange without added fat.....	2,054.0	1,154.5	40.5	12.9	836.0	10.1
Wheat biscuit.....	424.0	33.9	46.7	12.7	322.2	8.5
Fruit.....	1,225.0	1,065.8	12.2	-----	147.0	-----
Sugar.....	86.0	-----	-----	-----	86.0	-----
Total food consumed.....	3,789.0	2,254.2	99.4	25.6	1,391.2	18.6
Feces.....	93.0	-----	28.8	16.8	38.5	8.9
Amount utilized.....	-----	-----	70.6	8.8	1,352.7	9.7
Per cent utilized.....	-----	-----	71.0	34.4	97.2	52.2
Experiment No. 269, subject O. E. S.:						
Blanc mange, without added fat.....	2,222.0	1,249.0	43.8	14.0	904.3	10.9
Wheat biscuit.....	365.0	29.2	40.1	11.0	277.4	7.3
Fruit.....	636.0	553.3	6.4	-----	76.3	-----
Sugar.....	226.0	-----	-----	-----	226.0	-----
Total food consumed.....	3,449.0	1,831.5	90.3	25.0	1,484.0	18.2
Feces.....	110.0	-----	33.5	11.7	55.2	9.6
Amount utilized.....	-----	-----	56.8	13.3	1,428.8	8.6
Per cent utilized.....	-----	-----	62.9	53.2	96.3	47.3
Average food consumed per subject per day	1,264.1	720.1	33.3	8.8	495.7	6.3

Samples of the blanc mange (containing only small amounts of milk fat) and of the wheat biscuit (containing cereal fat) were analyzed, and in the calculation it has been assumed on the basis of a previous investigation ¹ that 5 per cent of the milk fat and 10 per cent of the wheat fat are undigested. The difference between the total ether extract of the feces and the amount of unutilized fat (5 per cent of milk fat and 10 per cent of wheat fat) is taken to be the amount of metabolic products occurring in the ether extract. In the following table are given the necessary data from the four basal ration experiments for obtaining the average percentage of metabolic products occurring in the ether extract of the feces. This value is a percentage of the weight of water-free feces.

Allowance for metabolic products.

	Experi- ment No. 266, sub- ject H. F. B.	Experi- ment No. 267, sub- ject D. G. G.	Experi- ment No. 268, sub- ject R. L. S.	Experi- ment No. 269, sub- ject O. E. S.
	<i>Grams.</i>	<i>Grams.</i>	<i>Grams.</i>	<i>Grams.</i>
Weight of water-free feces.....	136.0	87.0	93.0	110.0
Milk fat in blanc mange.....	14.5	12.1	12.9	14.0
Vegetable fat in wheat biscuit.....	17.8	10.0	12.7	11.0
Total ether extract of feces.....	11.8	8.3	16.8	11.7
Undigested milk fat in feces (estimated).....	.7	.6	.6	.7
Undigested wheat fat in feces (estimated).....	1.8	1.0	1.3	1.1
Metabolic products in ether extract of feces.....	9.3	6.7	14.9	9.9
Per cent of water-free feces computed as metabolic prod- ucts in ether extract of feces.....	6.84	7.70	16.02	9.00

¹ Connecticut Storrs. Sta. Rpt. 1899, p. 104.

The average amount of the water-free feces occurring as metabolic products in the ether extract is, accordingly, 9.89 per cent. The method of making the allowance is indicated by the following equations:

$9.89 \times (\text{weight of water-free feces}) = \text{metabolic products.}$

$(\text{Total ether extract}) - (\text{metabolic products}) = \text{unutilized fat.}$

$(\text{Utilized fat}) \div (\text{total fat eaten}) = \text{per cent of digestibility.}$

Applying these equations to the values which express the comparative digestibilities of the fats studied, the coefficients of digestibility are increased to 97.3 per cent for lard, 93.1 per cent for beef fat, 87.6 per cent for mutton fat, and 97.1 per cent for butter.

Should the percentage of metabolic products be based on the total weight of food as eaten, rather than on the weight of water-free feces, this value is found to be 0.27 per cent. The corresponding availabilities of the four fats, in the order studied, then become 97.3 per cent, 93.0 per cent, 86.8 per cent, and 96.9 per cent. That these values should agree so closely with those based on the weight of water-free feces is in accordance with the theory proposed by Prausnitz,¹ that the amount of metabolic products occurring in the feces is directly dependent upon the character and quantity of the ingested food—that food materials do not leave residues for feces, but produce feces composed principally of metabolic products.

GENERAL DISCUSSION.

All the fats included in this series of experiments were well assimilated, the coefficients of digestibility ranging from 97 per cent for butter to 88 per cent for mutton fat. The average amounts of fat eaten per subject per day during these experiments were 90 grams of lard, 100 grams of beef fat, 53 grams of mutton fat, and 100 grams of butter.

The average amount of protein consumed daily by the subjects was somewhat lower than that specified in dietary standards, but it was only limited by personal choice, as the subjects were permitted to eat as much of the wheat biscuit as they desired. Moreover, since only the fat portion of the diet was under consideration, it was not considered essential to maintain any special nitrogen level.

The values for the digestibility of the carbohydrate content of the diets were 96, 97, 97, and 96 per cent, for all practical purposes identical with its digestibility in the ordinary mixed diet, for which the average value is 97 per cent.²

The average energy value available per man per day as calculated by the usual factors and the coefficients of availability found in the digestion experiments was 2,235 calories for the lard, 2,730 calories for the beef fat, 2,145 calories for the mutton fat, and 2,420 calories for the butter diet. These energy quantities would be insufficient for

¹ Ztschr. Biol., 30 (1894), No. 12, p. 335.

² Connecticut Storrs Sta. Rpt. 1901, p. 245.

severe muscular activity, but should meet the needs of those following sedentary occupations.

It is interesting to know whether or not the presence in the diet of the different fats in considerable quantity affects the digestibility of the other constituents and the coefficient of availability of the ration as a whole. It has been shown by work previously reported¹ that the total available energy and the "coefficient of availability of energy" can be calculated with reasonable accuracy. The average coefficients of availability of energy for the rations as calculated were 93.0 per cent, 92.7 per cent, 91.5 per cent, and 93.9 per cent for the diets containing lard, beef fat, mutton fat, and butter, respectively. These values agree with one another closely and are somewhat higher than the value 91 per cent which has been found to represent the coefficient of availability of energy of the ordinary mixed diet.² It is reasonable to conclude, therefore, that the different fats did not exercise any unusual effect upon the digestibility of the other constituents of the rations.

The statement has frequently been made that the coefficients of digestibility of fats are directly related to the corresponding melting points. The melting points of samples of the fats studied or of samples of fats similarly prepared are reported in the table below together with a compilation of values³ determined by several investigators giving, presumably, the average range found in samples fairly true to name. The variation in the melting points of different samples of the same fat is consistent with the view that the melting points differ with the part of the body in which the fat is found and also with the animal from which it is taken.

Comparison of digestibility and melting point.

Fat studied.	Coefficient of digestibility.		Melting point.	
	Determined.	With allowance for metabolic products.	Authors' determinations.	Compiled average values. ¹
	<i>Per cent.</i>	<i>Per cent.</i>	<i>Degrees C.</i>	<i>Degrees C.</i>
Butter fat.....	94	97	32.0	28-36
Lard.....	94	97	35.0	30-44
Beef fat.....	89	93	45.0	42-50
Mutton fat.....	80	88	50.0	47-49

¹ Allen's Commercial Organic Analysis. Philadelphia: Blakiston's Son & Co., 1910, 4. ed., vol. 2, p. 72.

It seems fair to conclude that of those tested the fats of low melting points are capable of more complete assimilation than those which have a high melting point.

² Connecticut Storrs Sta. Rpt. 1899, p. 104.

³ U. S. Dept. Agr., Expt. Sta. Bul. 136 (1903), p. 113.

⁴ Allen's Commercial Organic Analysis. Philadelphia: Blakiston's Son & Co., 1910, 4. ed., vol. 2, p. 72.

Many more culinary and table fats are being studied and it is expected that it will be possible to judge whether this phenomenon is merely applicable to the instances cited or whether in general the coefficient of digestibility decreases as the melting point increases.

In the beef-fat experiments, in which approximately 140 grams of fat were consumed per day, the subjects reported a tendency toward a laxative condition, which was not noted when the amount of fat consumed was decreased. As no such condition resulted from eating the other fats, it would seem from the information at hand that the limit of tolerance for these may have been higher than for beef fat. Information in this regard is of considerable interest especially when it is desirable to make use of a diet containing an excessive amount of fat.

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Contribution from the Office of Markets and Rural
Organization, CHARLES J. BRAND, Chief.



Washington, D. C.



November 26, 1915

THE HANDLING AND MARKETING OF THE ARIZONA- EGYPTIAN COTTON OF THE SALT RIVER VALLEY.

By J. G. MARTIN, *Investigator in Cotton Marketing.*

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INTRODUCTION.

Since 1913 special work upon the handling, classing, and marketing of the long-staple varieties of cotton grown in this country from Egyptian seed has been under way. Basic work was done during that year, and aid was given by the Department of Agriculture in continuing certain phases of it during the season of 1914.

The work in 1913 was undertaken at a most opportune time, in the month of October, when picking had just begun. It was possible, therefore, to observe closely not only the condition of the cotton in the field, the methods of picking, handling, and storage of the seed cotton on the farms and at the gins, but also the ginning of the cotton on roller gins. This opportunity of watching the handling of Egyptian cotton from the time it is picked until it is loaded into cars preparatory to its departure for the mills made it possible to note accurately the effect of proper and improper handling of the cotton.

NOTE.—This bulletin should be of interest to growers in Arizona and in California, and to dealers in Yazoo and Mississippi Delta cotton. It should be of interest to spinners in New England and the Carolinas and to spinners of fine yarn in England and on the Continent.

The purpose of this bulletin is to record the results of these investigations, with special attention to the handling and marketing of cotton, and it records the results of the assistance given by the chief of the office of Markets and Rural Organization in cooperation with the Southwestern Cotton Committee.¹

NECESSITY FOR CLEAN PICKING.

The Egyptian cotton boll is three lock and somewhat smaller than the average boll of short-staple cotton grown in the Southern States, and its small size and sharp-pointed burr make clean picking a more difficult task than is the case with ordinary Upland cotton. Since the long, silky fibers of the Egyptian cotton are to be used in the manufacture of fine combed yarns, a great majority of which are mercerized and go into the making of fine goods that resemble silk, it is essential that it be picked free of leaf and hulls. The roller gin does not clean the foreign matter from the seed cotton as some saw gins do, hence the necessity for clean picking by hand. In order to accomplish this end it has been found necessary to pay as high as 2 cents per pound for picking, which enables the laborer to pick the Egyptian cotton carefully and still make a good wage for his day's work.

The cotton pickers of the Salt River Valley are white settlers from Texas and Oklahoma, Mexicans, and Indians from the Papago and Pima Reservations. At first there was a tendency on the part of the pickers to gather the cotton rapidly, making a very large wage at the expense of the grade of the cotton. To avoid this difficulty the farmer was advised that the price and quick sale of his cotton depended largely on the grade, which meant that he must insist upon his cotton being picked clean. The results of clean picking can be seen clearly in the table of grades (see Table II, p. —). It will be noted that the Mesa and Tempe cotton was picked cleaner than that grown elsewhere in the valley. This clean cotton may be accounted for by the fact that the Indians, who are known to be slow but good pickers, gathered a large part of the Mesa and Tempe crop. This is the first time that Indians have been used as cotton pickers in a commercial way (see PL I, fig. 1).

¹ This committee is composed of five members, as follows, the first named being chairman: C. S. Scofield, agriculturist in charge of Western Irrigation Agriculture; W. T. Swingle, physiologist in charge of Crop Physiology and Breeding Investigations; O. F. Cook, bionomist in charge of Crop Acclimatization and Cotton Breeding Investigations; T. H. Kearney, physiologist in charge of Alkali and Drought Resisting Plant Investigations; Charles J. Brand, chief, office of Markets and Rural Organization in charge of the Cotton Handling and Marketing Investigations herein described. This committee was organized to study the economic and agricultural problems connected with the establishment of this new industry, especially on the irrigation projects of the Salt River Valley of Arizona and the Imperial Valley of California, and it is practically to this committee that the industry in these regions owes its origin and development. For a description of the establishment and development of the Arizona-Egyptian cotton industry in the Southwest, see Scofield, C. S., Kearney, T. H., Brand, C. J., Cook, O. F., and Swingle, W. T., Community production of Egyptian cotton in Arizona. U. S. Department of Agriculture Bulletin 332.

As a whole, the picking in the Salt River Valley was very fair, as will be seen by Tables I, II, and III, which show a good average grade. Table II shows that by careful and clean picking the greater portion of the crop can be made to grade Choice and above. It will be noted that there were only 72 bales of Medium and 274 bales of Standard out of the crop of 1,237 bales ginned at Mesa.

STORAGE OF SEED COTTON.

The storage capacity for seed cotton at the gins was inadequate during both seasons, and as there were no seed-cotton houses on the farms, the cotton in a great many instances had to be piled in a corner of the field, on the ground, until enough could be accumulated to make up a wagonload. The majority of the farmers live at a considerable distance from the gins, and the expense of hauling only a fraction of a wagonload is prohibitive. At the same time, the cotton left on the ground was subject to damage by exposure to heat, heavy dews, and rains. Seed cotton, loaded in wagons, was left standing in the fields, in barnyards, and at the gins. The cotton neglected in this manner was subject to damage by exposure, as it absorbed a certain amount of moisture and was ginned damp. Damp or wet cotton does not gin smoothly, but produces a curly and matted condition of the fiber, which lowers its grade and value. Unfortunately, the result was very marked in this case. In January, after a period of rainy weather which lasted several days, some of the cotton was so wet when ginned that the friction of the rollers against the knife-edge heated the cotton greatly, thus subjecting it to undue damage. The curly condition due to the ginning of wet cotton was very noticeable after each rain.

GINNING THE ARIZONA-EGYPTIAN COTTON.

The first half of the crop ginned in 1913 contained a great many crushed seed in the cotton; in fact, during the first part of the season all of the roller-gin stands at Mesa and Chandler were crushing the seed. It was found that the amount of crushed seed was greater at the ends of the rollers, where at times whole seeds would work around the end. Crevices were found in the rollers between the walrus-hide strips, where the seed would catch and be conveyed to the knife-edges. Here they would be crushed between the knife and the roller, passing into the lint. This defect in the gins was discovered and remedied.

The ginner at Chandler discovered that the rollers were 2 inches too short for the frame of the gin. The rollers were extended to make them the proper length, thereby preventing further crushing of seed. With this fault corrected and the walrus-hide covering on the rollers made smooth and free from crevices, the gins worked with satisfactory results. It was also found that on dry and well-handled seed cotton the gins did excellent work.

As it was about the middle of January when these corrections were made it was not until after that time that the best grades of cotton were produced at the gins. Under ordinary conditions it is usual to expect the best grades to be made from the first cotton picked, but due to these conditions at the gins the higher grades were made from that part of the crop which was picked in the middle of the season. This accounts for the relatively few bales of Fancy found in the crop. (See Tables I, II, and III, pp. 9 and 10.)

In the season of 1914 the Tempe and Mesa gins were equipped with cleaners and feeders which, when the cotton was dry, beat a great deal of the leaf out of the cotton before it went into the gin stand. The manager of the Tempe gin, finding it essential to have the cotton dry in order to do proper ginning and also to lessen the wear on the walrus-hide rollers, arranged a system by which the seed cotton, when damp, was drawn by suction from the wagon, dropped through the center flue of the storehouse, a distance of about 40 feet, then was conveyed through the air-blast pipes for approximately 40 feet, returned to the seed house, and then conveyed to the gin stands. This process dried the lint considerably and allowed the cleaners to knock the leaf out of the cotton, thereby improving its grade.

SAMPLING COTTON AT THE GIN STANDS.

In order to secure a thoroughly representative sample of the Arizona-Egyptian cotton which would show the average quality of the cotton in the bale, the following method of sampling at the gin stands was inaugurated:

The workman whose duty it was to gather the cotton from the gin stands and convey it to the press box was instructed to take a handful of lint cotton from each gin stand when a wagonload of seed cotton was started through the gin, then to take another when the seed cotton was about half ginned, and a third when the ginning of the bale was nearly completed. It will be seen that by this method samples were secured which represented the cotton in different parts of the bale. In the case of gins operating 10-roller gin stands the taking of samples from each gin stand, at the beginning, middle, and completion, will give samples from 30 parts of the bale. The amount of cotton thus taken from the bale will weigh about 1 pound, and will be of sufficient size to split into types, on which sales may be made, and will do away with the practice of cutting the bagging at each sampling. Such cutting of the bagging not only wastes as much cotton as is taken out at the gins for the sample, but opens a way for further waste and damage, and also causes greater danger of fire. The effect of cutting the bagging of a bale several times for sampling purposes is shown by Plate I, figure 2, which represents an Arizona-Egyptian bale as it arrived in Liverpool.

BALING AND COVERING THE COTTON.

All press boxes in the Salt River Valley are standard size, i. e., 27 by 54 inches, thus pressing a bale to approximately 12 pounds density to the cubic foot. This size is known to the cotton trade as a flat or uncompressed bale, and is similar to the great majority of the bales put up by the gins throughout the South.

It is very difficult to secure bales of regular and uniform weight, as the weight and size of the bale depend upon the weight of seed cotton brought to the gin by the farmer. The manager of the gin weighs the wagon and cotton together on platform scales, and by deducting the weight of the wagon from the total he obtains the weight of the seed cotton. From the weight of the seed cotton the ginner is able to estimate the weight of the bales he will make out of the wagonload of cotton. It is undesirable to have a number of small lots of cotton left over to be stored; therefore the ginner uses all of the seed cotton which the farmer has on his wagon and distributes the weight into the most convenient number of bales. He may be able to make either three light-weight or two heavy bales.

The first cotton baled in the Salt River Valley was not covered sufficiently. Side strips were not used, nor were the heads properly covered. One of the gins used second-hand sugar bags as a wrapping, which were too light in weight and were more or less rotten, thus affording very little protection. Plate I, figure 2, shows that the covering of the cotton thus baled was not such as to afford protection against country damage and fire under the present method of sampling. During 1913 one gin used a good quality of bagging and baled the cotton properly. Every gin should use a good quality of new bagging or a heavy burlap of sufficient strength to withstand rough handling.¹

ADVISABILITY OF GIN COMPRESSION.

A great improvement in the existing methods of marketing the Arizona crop could be made by the use of gin compresses. There are a number of well-known types of presses which give good results with cotton from the condensers of the saw gin outfit. The roller gin does not adapt itself to feeding into the roller feeder type of press. A gin compress without the roller feature is as well adapted to pressing cotton from a roller as from a saw gin. The establishment of such a press for general use in Arizona might introduce a great saving to the producer in the way of samples, compress fees, and freight charges. It is a well-known fact that the gin-compressed bale is easier to handle and takes up less space (see Pl. I, fig. 3, and Pl. II, fig. 2), as the cotton is usually pressed to a density of 30 pounds per

¹ No. 2 Calcutta bagging has been found to be of suitable weight and strength.

cubic foot, thus allowing 100 bales, which constitutes a unit sale and shipment of cotton, to be loaded into a standard freight car 36 feet long, whereas only 40 bales of flat or uncompressed cotton can be loaded into a car of the same size. Cotton put up by a gin compress can be shipped by railroads to ship side at the compressed rate, and if requested, the steamship companies will make a better rate on cotton of 30 pounds density than on the old-style compress bale of about 22 pounds density, as a greater amount of this cotton can be stored in the same space in the hold of a steamship.

Another great advantage which gin compression affords is that if the bagging remains uncut, a farmer who grows a particularly good quality or variety of cotton would have his identifying mark on every bale. If a farmer furnished a good quality of cotton under his mark, the spinners would learn to recognize it and to demand a certain mark or brand of cotton suitable for their requirements.

TAGGING, MARKING, BRANDING, AND WEIGHING THE COTTON.

In order to secure accuracy and safety in handling, the following method of procedure was recommended by the representative of the Department of Agriculture and used during both seasons:

Tagging.—As the bale came out of the press box a fair-sized heavy tag was attached by means of a double copper wire. On this tag was printed the name of the gin and location and a serial number. The tag carried one or more coupons bearing the corresponding serial number. One of these coupons was detached and placed in the sample of the cotton.

Marking.—The marking was done by means of stencils, with 4-inch letters. The size of the letters to be used should be governed by the quality of the bagging on the bale. For a covering of burlap a stencil with letters of 4 inches is large enough to be legible. On regular jute bagging weighing 2 pounds to the yard 6-inch letters should be used. Six-inch letters are large enough for marking cotton covered with any well-woven bagging.

Branding.—The planter's mark and the gin number were placed on the head of each bale, and the bale was branded on the sample-hole side. It was recommended that each organization of cotton growers adopt a brand which would identify the cotton not only as Arizona-Egyptian cotton, but as Egyptian cotton grown by a particular organization.

Weighing.—The Arizona-Egyptian cotton is sold on net weight—that is, on the total weight less the tare. The tare of a gin-compressed bale can be determined more accurately than the tare of one which is flat or uncompressed. The bale is uniform in size and shape, and for this reason the amount of bagging and ties will be of uniform weight. Consequently when a gin-compressed bale is weighed at the gin the shipper knows exactly how many pounds to deduct for tare.

STORAGE OF GINNED EGYPTIAN COTTON.

Although there is very little rainfall in Arizona, it is at times sufficient to wet any baled cotton that is left uncovered and exposed to the weather, thus causing considerable country damage. The storing of cotton not only protects it against damage by the weather, but furnishes collateral security for obtaining loans by the farmer until he is prepared to sell. In the event that no warehouse is available the baled cotton should be removed from the gin platform to a cotton platform of sufficient distance from the gin to comply with insurance regulations. If this platform is not large enough for all of the cotton, it should be ranged in the yard on dunnage, which is formed by skids or stringers, to raise the bales at least 4 inches above the ground, thus leaving them high enough to prevent damage and to allow free circulation of air under the bales. These bales should be turned over at intervals in order to allow the under side to dry, as, in spite of the dunnage, it is liable to absorb a certain amount of moisture.

Information secured at the Mesa gin in January, 1914, serves to illustrate how quickly cotton will damage. Some of the cotton at Mesa was placed on the planks as described, and the remainder was left standing on the head of the bales on the ground. When the cotton was moved for shipment, it was found that the heads were damaged to an extent which ranged from 1 to 7 pounds per bale. (See Pl. III, figs. 1 and 2.) This damaged cotton was a total loss to the farmer, as the railroad and steamship companies have stringent rules regarding it. They will not accept cotton that is damaged unless a clause is attached to the bill of lading stating that the cotton is in bad condition. A bill of lading containing such a clause frequently is refused by the purchaser, or, if accepted, the cotton is subjected to a close scrutiny. In a case where damaged cotton is accepted, the buyer very often, in picking off the damaged parts, removes at the same time more of the good cotton than is necessary. This amount of damaged material removed from the bales reduces the weight of the cotton, and a claim for loss in weight is made against the shipper.

CLASSING THE ARIZONA-EGYPTIAN COTTON.

The Arizona-Egyptian cotton was a new variety for which no standards for grades or staples existed, and there were no terms other than those in use by the Egyptian cotton trade by which this new staple could be described, while for all other varieties there were standards in use with trade names which designate the quality by which the cotton is sold. Hence the evident need of types for classifying the new Arizona staple cotton.

The representative of the department during the season of 1913 established types which became fairly well known to the Salt River

Valley Cotton Association. The types were also used in part as a basis of business done with cotton merchants and mills in the East. During the season of 1914 work was continued on these types, taking into consideration the quality of the crop during both seasons, with the idea of perfecting them so that the Department of Agriculture could promulgate them later as standards.

The amount of leaf, trash, foreign matter, and dead cotton, and the color, are determining factors in establishing the grade. The bulk of the crop of cotton up to the time of the first killing frost should grade better than the basis grade, Choice, provided the cotton pickers exercise a due amount of care in picking. The plant is alive, the leaves firm, and the cotton is free of boll stain and can be picked free of leaf. After a frost the plants are killed, the leaves dry and shrivel up, breaking into small pieces which adhere to the cotton when picked from the open boll. The frost having killed the plant, the boll is forced open before all of the fibers are mature. The action of the frost on the sap in the cotton boll stains the lint, and also causes flakes of cotton in the boll to perish; that is, the staple or fiber is attacked by a fungus growth which discolors and weakens the fiber.

In making up types the following points were taken into consideration:

- (1) Amount of leaf, hulls, or foreign matter in the bale.
- (2) Color of the lint cotton.
- (3) Silkiness.
- (4) Amount of boll stain, dead cotton, etc.
- (5) Length of fiber.
- (6) Strength of fiber.
- (7) Uniformity of length.

The Arizona grades, as worked out during this investigation and study, with their equivalents in Egyptian cottons—corresponding to the Official Cotton Standards of the United States in leaf only—are as follows:

Fancy.—Clear and clean, creamy color (allows about as much leaf as Strict Good Middling, United States Government Standard), and is equal to Extra Fine Sakellaridis Egyptian.

Extra.—Clean, creamy or slight color (allows leaf about equal to Good Middling, United States Official Standard); equivalent to Fine Sakellaridis Egyptian.

Choice.—Allows color after frost (allows leaf equal to Strict Middling, United States Official Standard); equivalent to Good Sakellaridis Egyptian.

Standard.—(Leaf equal to Middling, United States Official Standard.) Equivalent to Fully Good Fair to Good Fair Sakellaridis Egyptian.

Medium.—(Leaf equal to Strict Low Middling, United States Official Standard.) Equivalent to Strictly Good Fair Sakellaridis Egyptian.



FIG. 1.—INDIAN COTTON PICKERS.

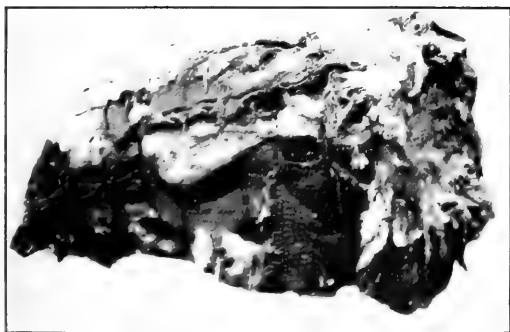


FIG. 2.—AMERICAN BALE IN LIVERPOOL, SHOWING
IMPROPERLY-COVERED COTTON.

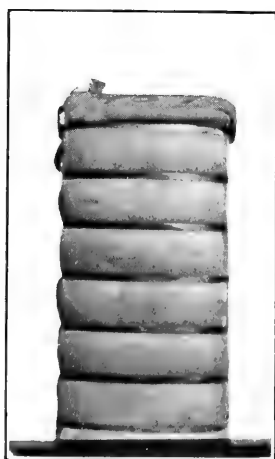


FIG. 3.—GIN-COMPRESSED BALE.



FIG. 1.—GIN OR "FLAT" BALES ON RIGHT; RAILROAD COMPRESSED BALES ON LEFT.



FIG. 2.—GIN-COMPRESSED BALES.



FIG. 1.—COTTON RESTING ON DUNNAGE.

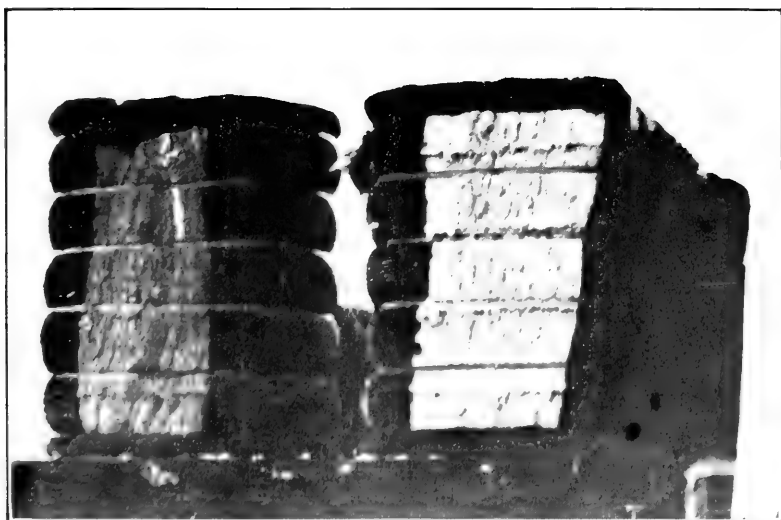


FIG. 2.—THE DARKENED SURFACE OF THE FIRST BALE SHOWS COUNTRY DAMAGE CAUSED BY THE FACT THAT IT WAS LEFT ON THE GROUND.

STAPLES.

The three staple lengths of the Arizona-Egyptian cotton were grouped as follows: The longest and best staple was named Sacaton, the next was named River, and the third Valley. The following is a comparison between the lengths of staple of the Arizona-Egyptian cotton and the varieties of Egyptian cotton:

The Sacaton staple is equivalent in length to that of the best Sakellaridis imported into this country.

The River staple is equivalent in length to that of the best Janovitch.

The Valley staple is equivalent to the best Mit Afifi.

This comparison was later confirmed by spinners of New Bedford, Mass., brokers throughout New England, by merchants in England, France, and Germany, and by the chairman of the arbitration committee of the Liverpool Cotton Association.

The New Bedford, Mass., fine-goods mills called the Sacaton staple $1\frac{7}{16}$ to $1\frac{1}{2}$ inches, River staple $1\frac{3}{8}$ to $1\frac{7}{16}$, Valley staple $1\frac{1}{4}$ to $1\frac{5}{8}$ inches in length; other mill points using such cotton will call the staple about one-eighth of an inch longer. These differences in the estimation of lengths are well known to the trade and prices for identical lengths and qualities are very similar.

The buyers for fine-goods mills of New England call the staple shorter than do the English, French, or German spinners. Prominent cotton merchants of Liverpool and Manchester, England, Havre, France, and Bremen, Germany, called the Sacaton staple 42 millimeters in length, which is equivalent to a fraction over $1\frac{5}{8}$ inches, while the chairman of the arbitration committee of the Liverpool Cotton Association declared it to be equal to the Egyptian variety of Sakellaridis.

The following tables are given to show the number of bales of each grade and staple ginned in each of the localities in which cotton was grown in the Salt River Valley during the season of 1913:

TABLES OF CLASSIFICATION OF ARIZONA-EGYPTIAN COTTON IN 1913.

[This cotton was classed in even-running lots of 25 and 50 bales each.]

TABLE I.—Class of Arizona-Egyptian cotton ginned at Chandler, Ariz.

Grades.	Sacaton staple.	River staple.	Valley staple.	Total.
	<i>Bales.</i>	<i>Bales.</i>	<i>Bales.</i>	<i>Bales.</i>
Fancy.....	1	2	3	3
Extra.....	39	54	93	93
Choice.....	20	35	15	70
Standard.....	9	62	47	118
Medium.....	1	16	16	33
Total.....	70	169	78	317

TABLE II.—*Class of Arizona-Egyptian cotton ginned at Mesa, Ariz.*

Grades.	Sacaton staple.	River staple.	Valley staple.	Total.
	<i>Bales.</i>	<i>Bales.</i>	<i>Bales.</i>	<i>Bales.</i>
Fancy.....	24	12		36
Extra.....	388	78		466
Choice.....	272	117		389
Standard.....	182	80	12	274
Medium.....	26	39	7	72
Total.....	892	326	19	1,237

TABLE III.—*Class of Arizona-Egyptian cotton ginned at Glendale, Ariz.*

Grades.	Sacaton staple.	River staple.	Valley staple.	Total.
	<i>Bales.</i>	<i>Bales.</i>	<i>Bales.</i>	<i>Bales.</i>
Fancy.....				
Extra.....				
Choice.....	1	5		6
Standard.....	6	31	4	41
Medium.....	7	46	8	61
Total.....	14	82	12	108

ADVANTAGES OF GRADING COTTON.

To conduct the business in the proper way, and in order to secure the best results, a buyer, in whatever line of business he may be, wishes to secure the material that is going to produce the desired result. For this purpose he will see that the material that he buys meets his requirements in every detail. This is true of the cotton manufacturer. A cotton-mill man who has sold a specific number of yarn requires a definite grade and staple of cotton in order to make this product. The broker has a certain knowledge of the requirements necessary to make the different yarns. The treasurer or president of the mill knows what kind of cotton he needs. He requests his broker to make him an offer of a specified number of bales, shipment to be prompt or equal portions of it to be made at stated intervals. Everything being satisfactory, the sale is consummated, and it then rests with the broker to secure the required cotton.

If he can buy the cotton in even-running lots, the broker offers it at a price which allows a small profit to himself. However, if he be compelled to buy the cotton unclassified, or in a "hog round" lot, of which perhaps 25 per cent may not be suitable for his needs, that amount of cotton has to be stored and disposed of in some other way. Therefore he must buy his cotton at a price that will allow carrying charges and insure a profit sufficient to cover a possible loss. From this it will be seen that if cotton is sold in "hog round" lots the price secured will not be as good as when the cotton is sold on grade, each grade bringing its own price. When a lot of cotton is sold at an

average price for the various grades composing it, the high or best grades do not yield a just return, and the farmer does not receive a fair value for his product. The farmer whose low grades are bought at the same price, however, receives too high a price, but it is at the expense of the farmer who is selling the high-grade cotton.

MARKETING OF ARIZONA-EGYPTIAN COTTON.

In 1913 and in 1914 the cotton associations of Arizona, after conference with officers of the department, sent a representative to New York, Boston, Providence, and other American cotton markets in which Egyptian cotton is sold. In 1914, through the Committee on Southwestern Cotton Culture, arrangements were also made for sending this agent on to England, France, and Germany to introduce the Arizona staple cotton in those countries, and arrangements were made for selling it. The declaration of war in August, 1914, however, caused all agreements to be canceled. Marketing conditions being abnormal in 1914, the descriptions of the work of these two seasons are given separately.

In 1913 members of the Southwestern Cotton Committee of the United States Department of Agriculture met with the members of the Arkwright Club of Boston, which is an organization composed of the leading spinners of New England, at the invitation of that club. Types of the Arizona-Egyptian cotton were exhibited and the quality of the cotton and other phases of the subject were discussed, and the members of the Arkwright Club apparently were very favorably impressed with the new long-staple crop of Arizona.

Also in this year a representative of the cotton growers of the Salt River Valley was given authority to sell, or to make the best arrangement possible, for all cotton belonging to members of the exchanges of the Salt River Valley. Types of the various grades and actual tagged samples, which represented lots of 50 bales each in even-running grade and staple, were made up and sent by this representative to show the quality of this cotton.

Sales of a part of the crop belonging to the members of the association were made direct to the cotton mills; the remainder was consigned to cotton brokers, who advanced from 12½ to 15 cents per pound, according to the class of cotton. This cotton was afterwards sold as classed out at prices that compared very favorably with sales made under similar market conditions of Egyptian cotton of similar staple and grade which was imported into this country. A small lot of the Arizona-Egyptian cotton was consigned to Liverpool, and on arrival in that market the greater portion of the cotton was sold at a very good price. These sales of the Arizona-Egyptian cotton serve to illustrate its comparative value with the Egyptian-grown cotton of similar grade and staple.

The best price obtained for this cotton in this country in 1913 was 22 cents, while a Liverpool merchant quickly bought the greater part of the offerings sent there for $11\frac{3}{4}$ pence, or $23\frac{1}{2}$ cents. At this time an order was received from a mill at Fall River, Mass., for 10 bales. As it was cheaper to reship to this country at a freight rate of 25 cents per hundred pounds than to ship from Mesa at a rate based on less than a carload shipment at \$3.25 per hundred pounds to Fall River, 10 of the bales consigned to Liverpool were shipped back to fill this order.

In 1914 Mesa was selected by the department's representative as the most central and convenient point for conducting the work toward establishing standards for the crop and the marketing of it according to these standards, because of its location in the district of the greatest cotton production, and because the Central Association of Egyptian Cotton Growers had established offices at that place for the handling and selling of the cotton crop of its members. Here headquarters was established and a suitable room was equipped for classing cotton.

The construction of a modern ginning plant at Tempe marked a distinct step in the development of the Central Association and of the Arizona-Egyptian industry during this year. The final satisfactory outturn of the 1913 crop, the long haul to the Mesa gin, and the inducements to an increased acreage caused the farmers to feel that the construction of this gin would be a good investment.

As the 1914 season was such an unusual one, and as the growers of the Salt River Valley succeeded in obtaining a comparatively good price for their cotton, a somewhat detailed description of the causes and methods is given here.

In the latter part of August, 1914, after the declaration of war by the European powers, the association sold 200 bales of cotton at prices equivalent to those on sales of similar grade made last season; that is, 22 cents was obtained for Extra, 21 cents for Choice, and $19\frac{1}{2}$ cents for Standard grade. This sale, No. 1, was made September 1, 1914, for 50 bales of Extra, 100 bales of Choice, and 50 bales of Standard cotton, respectively, half Sacaton and half River staple, at the prices quoted above, f. o. b. Mesa or Tempe, and freight allowance to mill points, less 22 pounds per bale tare, insurance, and interest from time of payment of draft until cotton reached the mill, final settlement being made on mill weights.

On September 10, 1914, eastern brokers agreed to take on consignment 500 bales of cotton, advancing 15 cents on Extra, 14 cents on Choice, $13\frac{1}{2}$ cents on Standard, and 12 cents on Medium grade, f. o. b. Mesa. This consignment was known as consignment No. 1.

On September 15, 1914, the association made their second sale. Sale No. 2 consisted of 200 bales of Standard at a slight decline from the original price.

Sale No. 3, of 200 bales, was made on September 15, 1914, after the market had declined materially. At the time of the sale, the prices seemed very low to the grower, but later they were compelled to sell at a price 1 cent per pound below these sales.

On September 19, 1914, consignment No. 2 was arranged with eastern brokers who took on consignment 1,000 bales of the Arizona-Egyptian cotton from the association, advancing a trifle less on each grade than in consignment No. 1. This consignment was sold a few days later on sale No. 5 at approximately 4 cents less for each grade, usual terms, than was obtained in sale 1.

On December 30, 1914, consignment No. 4 of 100 bales was made and shipped to brokers, who advanced 13 cents f. o. b. Mesa and Tempe on same. Later in the season it became evident that the association would not be able to fill sale No. 5 on account of the heavy rains of December, which lowered the grades to such an extent that there were very few bales of Choice and higher being ginned. As a compromise, the agents made an arrangement with the mill to which they sold the 1,000 bales of sale No. 5 to accept against that sale the 100 bales of Medium at the price of 15 cents f. o. b. Eastern points.

By these sales, the problem of marketing the crop during the season was solved.

The first Tempe cotton was classed October 5 and showed a very fair grade and a portion of it very good staple, although 3 bales, Nos. 4, 5, and 6, classed Fancy Valley, the highest grade and shortest staple. Later it was learned that these 3 bales were from volunteer or ratoon cotton, commonly called stump cotton, grown at Scottsdale. It was quite evident throughout the season that all cotton volunteered or grown from the stump was shorter in staple, weaker, and less silky than cotton grown from seed in the same field.¹

During the season of 1914 the rainfall was unusually heavy. Although the grades had been running lower than usual, it was not until October 14 that the first Standard grades appeared. Up to this date the low grades were not entirely due to the rains, but to careless picking and to the fact that damp cotton was ginned. The percentage of low grades in 1914 was much greater than in 1913. (See Tables I, II, III, and IV.)

When it seemed that shipping was quite safe from Egypt to England, and from England to the United States, the great pressure of the Egyptian crop was thrown on the market and there was a decline of several cents per pound in the price of Egyptian cotton. The third sale of 200 bales of Arizona-Egyptian was made at this time. Although the cotton market was demoralized and prices were very low, there was a market for the long-staple variety. On October 23,

¹ See Scofield, C. S., Kearney, T. H., Brand, C. J., Cook, O. F., and Swingle, W. T., Community production of Egyptian cotton in Arizona. U. S. Department of Agriculture Bulletin 332.

eastern brokers offered to take 600 bales on consignment, making substantially the same advance as before. This proposition finally terminated in a consignment of 1,000 bales, the agency advancing one-half cent per grade more than originally offered. On November 12, the same brokers telegraphed an offer on 500 bales, advising that they could sell 100 bales Extra at 17 cents and 400 bales Choice at 16½ cents. The association authorized them to sell the 500 bales if they could apply the cotton shipped on the first consignment, thereby terminating the expense of carrying charges on it. The cotton from consignment No. 1 was applied against sale No. 4.

On November 17 the agency telegraphed their representative, advising that they could sell 1,500 bales, 750 Extra and 750 Choice grade, half each of Sacaton and River staple, usual terms, for January, February, and March shipment, at a decline of a fraction of a cent below the last sale, f. o. b. New England mill points. On account of the great amount of lower-grade cotton which appeared so early in the season, it was deemed advisable to sell 1,000 bales of the grades of Extra, Choice, and Standard, shipment to be made as soon as cotton was ginned. All shipments of the above grades on consignments were to apply on this sale No. 5, with the stipulated privilege that in case the association could not supply the full 300 bales of Extra the difference in amount could be shipped in the grade of Standard at the price for Standard named in the sale. As the October rainfall in the Salt River Valley was the heaviest in years, and as the industry was so new that the effect of excessive rains on the cotton had not been determined, it was not possible to guarantee the delivery of 300 bales of the grade of Extra.

A slow, light rain began on December 17, 1914, and continued until December 28. During this time the cotton fields were so wet and muddy that picking ceased and the gins were forced to shut down.

On December 29 cotton picking was resumed generally over the Valley. The first cotton hauled in to the gins was very damp, leafy, and discolored. The seed cotton picked after the long, continuous rain, when ginned, turned out to be of a grade inferior to the lowest type, "Medium." Samples of the low-grade cotton were marked "Rain" and expressed to a firm with whom the association had been transacting business. It was asked to name the advance it would make on the cotton and to try to place it as soon as possible. It reported that it would be very hard to sell cotton that was lower in grade than Medium, and that it was in fact difficult to sell Medium. It refused to take the very low grades on consignment and did not wish to take more of the Medium, but did agree to advance as much as 11½ cents on it.

Later in the season, after a material advance in the market, the local exchange at Tempe sold for the central association of cotton

growers 100 bales of the cotton below the grade of Medium at 14 cents f. o. b. Phoenix. A few days later the eastern agency sold the Mesa 50 bales "Rain" at $15\frac{1}{2}$ cents landed eastern points. It sold the 19 bales of very low grade at $15\frac{3}{4}$ cents, and the Tempe 12 bales, which were below the grade of Medium, at $15\frac{3}{4}$ cents, all landed New England mill points, on usual terms.

The following detailed information gives account of the cotton ginned and the classification of all cotton handled in cooperation between the Office of Markets and Rural Organization and the Central Association during the season of 1914-15:

TABLES OF CLASSIFICATION OF ARIZONA-EGYPTIAN COTTON IN 1914.¹

[This cotton was classed in even-running lots of 25 and 50 bales each.]

TABLE IV.—*Class of Arizona-Egyptian cotton grown and ginned at Mesa.*

	Sacaton staple.	River staple.	Valley staple.	Total.
	<i>Bales.</i>	<i>Bales.</i>	<i>Bales.</i>	<i>Bales.</i>
Fancy grade.....	1			1
Extra grade.....	93	116	1	210
Choice grade.....	195	287		482
Standard grade.....	210	204		414
Medium grade.....	74	154	1	229
Below class.....	10	60	4	74
Total.....	583	821	6	1,410

¹ The Chandler Association leased their gin, and therefore are not cooperating with the central association. The Glendale Association planted short-staple cotton and changed their equipment to saw gin, and therefore are not represented in this table.

TABLE V.—*Class of Arizona-Egyptian cotton grown and ginned at Tempe.*

	Sacaton staple.	River staple.	Valley staple.	Total.
	<i>Bales.</i>	<i>Bales.</i>	<i>Bales.</i>	<i>Bales.</i>
Fancy grade.....			3	3
Extra grade.....	44	81	3	128
Choice grade.....	181	201	1	384
Standard grade.....	207	190		398
Medium grade.....	54	197		251
Total.....				1,164
Below class.....	7	115	1	123
Grand total.....				1,287

CONCLUSIONS.

The increase in the estimated size of the Salt River Valley Egyptian cotton crop from 280 bales in 1912 to 2,200 bales in 1913, and to 6,187 in 1914, demonstrates the peculiar fitness of this locality for the production of Egyptian cotton. The continued improvements in methods of handling and equipment will serve to improve the grade of the product, while the classing of the cotton will tend to secure a more stable market at better and more uniform

prices. Up to the present time the relatively small crop from the Salt River Valley has been so distributed that only a few spinners have been able to test this cotton. The testimony from a number of various sources, including some of the largest cotton firms, spinners, and exporters, indicates that the quality, character, and length of staple of this cotton is of such a nature as will establish for it a permanent market.

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UNITED STATES DEPARTMENT OF AGRICULTURE



BULLETIN No. 312



Contribution from the Bureau of Soils
MILTON WHITNEY, Chief

Washington, D. C.



November 5, 1915

PHOSPHATE ROCK AND METHODS PROPOSED FOR ITS UTILIZATION AS A FERTILIZER.

By WILLIAM H. WAGGAMAN and WILLIAM H. FRY.

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INTRODUCTION.

The basis of nearly all mixed fertilizers is water-soluble or so-called "available" phosphoric acid, which is produced by submitting bones, a mineral phosphate (apatite or phosphorite), or some other phosphate-bearing substance to a treatment by which the constitution of the original body is materially changed.

Our supply of bones is entirely inadequate to meet the present demands of the fertilizer industry, while apatite has proved objectionable because of the difficulty and expense of mining the mineral and on account of the quantity of fluorine which it contains. By far the greater part of the phosphate fertilizer is derived from phosphorites or amorphous phosphate rock, of which there are enormous deposits in the United States.

For many years the importance of the phosphate industry has been growing steadily. At present the conditions in Europe incident to war have temporarily curtailed the output of phosphate rock, in this country as well as abroad, but on the termination of hostilities the

production of fertilizers will undoubtedly continue its interrupted advance, and the phosphate industry will resume its former activity.

The output of phosphate rock in this country, by States, is given in Table I, and the production, exports, imports, and consumption in the United States for the last 14 years are given in Table II.

TABLE I.—*Production of phosphate rock in the United States.*¹

[In tons of 2,240 pounds.]

Phosphate.	1910		1911		1912	
	Tons.	Value.	Tons.	Value.	Tons.	Value.
Florida hard rock.....	392,088	\$2,940,660	474,094	\$2,953,606	536,379	\$3,218,274
Florida land pebble.....	1,637,709	6,550,836	2,020,477	6,809,007	2,043,486	7,101,186
Total, Florida.....	2,029,797	9,491,496	2,494,571	9,762,613	2,579,865	10,319,460
South Carolina land rock.....	185,000	786,250	² 169,156	673,156	² 131,490	524,760
South Carolina river rock.....	16,347	57,314	.....	.....	.....	.....
Total, South Carolina....	201,347	843,564	² 169,156	673,156	² 131,490	524,760
Tennessee.....	440,699	1,586,516	542,761	1,918,489	443,065	1,710,000
Other States.....	10,095	40,380	³ 10,505	39,882	² 11,612	46,450
Total, United States....	2,681,938	11,961,956	3,216,993	12,394,140	3,166,032	12,600,670

Phosphate.	1913		1914	
	Tons.	Value.	Tons.	Value.
Florida hard rock.....	485,811	\$3,206,343	² 309,689	² \$1,912,197
Florida land pebble.....	2,043,403	6,334,549	² 1,829,202	² 5,442,547
Total, Florida.....	2,529,214	9,540,892	² 2,138,891	² 7,354,744
South Carolina land rock.....	.....	.....	² 106,919	² 415,039
South Carolina river rock.....	.....	.....	.....	.....
Total, South Carolina....	.....	.....	² 106,919	² 415,039
Tennessee.....	434,193	1,628,224	² 483,203	² 1,822,770
Other States.....	⁴ 99,600	⁴ 398,272	² 5,030	² 15,488
Total, United States....	3,063,007	11,567,388	² 2,734,043	² 9,608,041

¹ Statistics collected by Mineral Industry, except as otherwise noted.

² Reported by the U. S. Geological Survey.

³ Idaho, Utah, and Wyoming.

⁴ Figures include production of South Carolina and other States not separately mentioned.

TABLE II.—*Statistics of phosphates for the United States.*¹

[In tons of 2,240 pounds.]

Year.	Production.	Imports.	Exports. ²	Consumption.	Year.	Production.	Imports.	Exports. ²	Consumption.
1901.....	1,483,723	180,714	729,539	934,898	1908.....	2,375,031	26,734	1,196,175	1,205,590
1902.....	1,600,813	145,793	802,086	944,250	1909.....	2,463,766	11,903	1,020,556	1,455,113
1903.....	1,581,576	153,972	785,259	950,289	1910.....	2,681,938	19,319	1,083,037	1,618,220
1904.....	1,874,428	166,090	842,484	1,198,034	1911.....	3,216,993	16,153	1,246,577	1,980,569
1905.....	1,933,286	82,072	934,940	1,080,418	1912.....	3,166,032	28,821	1,206,520	1,988,333
1906.....	2,052,742	46,228	904,214	1,194,756	1913.....	3,062,975	26,408	1,338,450	1,724,525
1907.....	2,251,459	25,896	1,018,212	1,259,143	1914.....	2,734,043	.....	964,114	1,769,929

¹ Production statistics of 1901 and subsequent years, except 1905 to 1913, are those of the U. S. Geological Survey and are based on marketed products.

² Neglecting the insignificant exports of foreign products.

The various deposits of phosphate differ considerably in their geologic occurrence and age, as well as in their physical properties and chemical composition.

The value of a phosphate deposit depends primarily on the grade of the rock, but the mode of occurrence, accessibility, and distance to markets are also factors of the utmost importance in determining its economic value.

The location and character of the American phosphate deposits, their geological occurrence and origin, the methods of mining and extracting the rock, and the cost of production at the various phosphate fields have been described in some detail in a number of papers,¹ but a brief description of the more important deposits is given here in order to compare their possibilities in the economic production of phosphoric acid and soluble phosphates.

PHOSPHATE DEPOSITS OF THE UNITED STATES.

FLORIDA HARD-ROCK PHOSPHATE.

The Florida hard-rock regions lie toward the west coast of the Florida Peninsula and extend from Suwanee and Columbia Counties southward to Citrus and Hernando Counties—a distance of over 100 miles. The mines are reached by both the Atlantic Coast Line Railroad and the Seaboard Air Line Railway, or spurs from these roads. The rock is hauled to the seaports on both the east and west coasts and loaded for shipment abroad.

The rock belongs to the Middle Tertiary period and occurs in irregular pockets embedded in a matrix of sand clay and soft phosphate, the whole usually resting on a limestone. In general the phosphate is a hard, close-grained, nodular, white or cream-colored rock containing from 75 to 80 per cent tricalcium phosphate (bone phosphate of lime), less than 3 per cent of the combined oxides of iron and aluminum, and small percentages of lime carbonate. The remainder of the material is largely silica.

Owing to the pockety nature of the deposits and to the fluctuations in the richness of the phosphatic matrix, the average cost of mining hard-rock phosphate is quite high, but the excellent grade of the product is such that it has heretofore found a ready market in European countries.

FLORIDA LAND-PEBBLE PHOSPHATE.

The land-pebble phosphate area at present productive lies to the south of the hard-rock regions in Polk and Hillsboro Counties.

The mines are reached by the Atlantic Coast Line Railroad and the Seaboard Air Line and the Charlotte Harbor & Northern Railways, or spurs from them.

¹ Bul. 69, 76, 81, Bureau of Soils, U. S. Dept. of Agr.; Bul. 18, U. S. Dept. of Agr.

Most of the rock is hauled to Tampa and Port Tampa and there shipped by water to Europe or to the east coast of the United States. The rock belongs to a more recent period than the hard-rock phosphate and is much more regular in its occurrence. As a whole the rock consists of medium-sized, light-gray pebbles somewhat softer than and not of as high grade as the hard-rock phosphates. Its content of tricalcium phosphate runs from 68 to 75 per cent and it contains as a rule less than 4 per cent of iron and aluminum oxides.

The hydraulic method of mining is practiced almost entirely in the pebble regions, and on account of the uniformity of the deposits and the ease with which the material can be handled the rock can be produced very cheaply. Pebble phosphates are by far the most extensively mined of all the American deposits, and up to the year 1914 the output from these fields steadily increased. The consumption of the product has heretofore been about equally divided between this country and Europe.

TENNESSEE BROWN-ROCK PHOSPHATE.

The brown-rock phosphate of Tennessee occurs in the central part of the State, extending in a general north and south direction from the northern to the southern boundary line. The most important deposits so far exploited occur in Sumner, Davidson, Williamson, Hickman, Maury, Lewis, and Giles Counties. The deposits are reached by the Louisville & Nashville and the Middle Tennessee Railroads and the Nashville, Chattanooga & St. Louis Railway. The deposits in Davidson and Sumner Counties have easy outlet to the Cumberland River.

The brown rock is of Ordovician age and in general consists of beds of brown porous plates of varying thickness overlying the original or slightly altered phosphate limestone from which it is derived. Frequently the beds of brown rock are much disintegrated and require special machinery to separate the phosphate from the impurities with which it is mingled. The brown-rock phosphate, as separated by mechanical means, contains from 72 to 78 per cent tricalcium phosphate and from 3 to 5 per cent of iron and aluminum oxides. Practically all of the brown-rock phosphates is now consumed in this country.

TENNESSEE BLUE-ROCK PHOSPHATE.

The important deposits of blue-rock, or Devonian, phosphate in Tennessee lie along Leatherwood Creek, in the western part of Maury County, south and east of Centerville in Hickman County, on both sides of Swan Creek in Hickman County, and in the eastern part of Lewis County near Gordonsburg. The mines are reached by the Louisville & Nashville and the Middle Tennessee Railroads and the Nashville, Chattanooga & St. Louis Railway. The Duck River is

the only navigable stream convenient to the blue-rock fields, and this river has not been used for shipping the rock in recent years. The blue-rock phosphate, as its name implies, is a massive grayish-blue or black rock, composed of flattened ovules and the waterworn casts of phosphatic shells. It weathers on exposure to a rusty yellow.

The beds vary from 1 foot to 4 feet in thickness and are overlain normally by massive blue-black shale. In some localities the blue rock directly overlies the brown phosphate, making the mining of the two types quite profitable.

As a rule the blue rock is of lower grade than the brown, but its content of tricalcium phosphate varies all the way from 60 to 80 per cent, the average content being not far from 72 per cent. The oxides of iron and aluminum are as a rule less than 3 per cent. The cost of mining blue-rock phosphate is about \$2.50 per ton.

TENNESSEE WHITE-ROCK PHOSPHATE.

The deposits of white-rock phosphates so far exploited lie in Perry and Decatur Counties, both east and west of the Tennessee River. Some of the deposits in Decatur County are not far from a branch of the Nashville, Chattanooga & St. Louis Railway at Parsons, Tenn., but the only ready means of transportation afforded the present mines in Perry County is the Tennessee River, which is from 4 to 6 miles distant.

The white-rock phosphate is of secondary origin and is more recent than either the blue or brown phosphate. It resembles somewhat the hard-rock phosphate of Florida and some of it is fully as high grade. Picked samples contain as high as 85 to 90 per cent of tricalcium phosphate, with only a small percentage of iron and aluminum oxides. In carload lots the rock will grade from 72 to 78 per cent tricalcium phosphate.

Because of the irregularity of the deposits and the lack of adequate transportation facilities the white phosphates have been exploited only to a very limited extent. It is doubtful whether these deposits will be extensively developed before the more accessible brown-rock and blue-rock fields have been depleted. No mining has been done in these regions in recent years, so that it is difficult to arrive at the actual cost of production. The average cost of producing white-rock phosphate would probably be slightly more than that of mining blue-rock phosphate.

SOUTH CAROLINA PHOSPHATE.

The phosphate area of South Carolina lies along the coast in a belt which is in places fully 20 miles wide, extending from the Wando River in Charleston County to the Broad River in Beaufort County. The rock is of Tertiary age and occurs as nodules and boulders embedded in a matrix of sand and clay. The beds have an average

thickness of about 1 foot and are mined by means of grab buckets or clam-shell dippers.

The rock as a whole consists of gray nodules of medium hardness, frequently much pitted and the holes filled with clay or calcareous mud, which must be removed by a washing process.

The average grade of the marketed product is about 61 per cent tricalcium phosphate. The average cost of producing South Carolina phosphate is not far from \$3.46 per ton, including interest, overhead, etc., and the rock, on board cars at the mines, brings about \$4 per ton.

Since the discovery of the higher grade and more cheaply mined phosphates in Florida and Tennessee, the exploitation of South Carolina rock has gradually fallen off. Most of the rock now mined is consumed locally for the manufacture of acid phosphate and double acid phosphate. The latter product, being very rich in soluble phosphates; will stand the cost of transportation.

THE WESTERN PHOSPHATES.

The western phosphate fields are located in southeastern Idaho, western Wyoming, northern Utah, and western Montana. The regions in which the phosphate has been mined or developed so far lie in southeastern Idaho, near the little towns of Soda Springs, Georgetown, and Montpelier on the Oregon Short Line Railroad; along the western front of the Sublette Mountain Range, near Border Station on the Idaho-Wyoming border; at the south end of this same mountain range, about $1\frac{1}{2}$ miles from Cokeville, Wyo., which is also on the Oregon Short Line Railroad; and in the Beckwith Hills in southwestern Wyoming and in northern Utah along the western front of the Crawford Mountains, about 5 miles from Sage Station, Wyo. Practically no development work has been done in Montana, but the phosphate has been recognized near Melrose, Mont., a town on the Oregon Short Line Railroad, and also at Garrison, Philipsburg, and Cardwell on the Northern Pacific Railway from 40 to 70 miles north of Melrose.

The topography of much of the phosphate area is extremely rugged, but many of the beds of phosphate are readily accessible and within easy reach of the railroads mentioned or possible spurs from them.

The western phosphates are original sedimentary deposits laid down when that portion of the earth's surface was submerged in water. The rock is of Carboniferous age and occurs in beds from 2 to 6 feet thick, overlain by limestone and phosphatic shales.* It ranges in color from light gray to jet black and in texture from a readily crushed, coarsely oolitic material to a hard massive rock difficult to crush. The rock varies in its phosphate content from 65 to 75 per

cent tricalcium phosphate, with only very small percentages of iron and aluminum oxides. The average cost of mining the western phosphate is from \$1.50 to \$2 a ton.

Because of their great distance from the fertilizer market, the western deposits have been mined to a very small extent, but the tonnage of high-grade rock in this region far surpasses that of any other area yet discovered.

THE PHOSPHATES OF ARKANSAS.

The phosphates of Arkansas are not generally considered of great economic importance, for, though small bodies of high-grade rock have been found in several localities, the average phosphate content is far below that of the rock mined in Tennessee and Florida.

Mining has been conducted to a considerable extent only in the northern part of the State, in Independence County, about 12 miles from Batesville, a town on the Missouri Pacific Railway. Here the phosphate rock is of Silurian age and occurs in two strata, one directly overlying the other. The upper stratum (from $3\frac{1}{2}$ to 6 feet thick) is the only one considered worth mining, and averages about 55 per cent tricalcium phosphate, with 5 or 6 per cent of the combined oxides of iron and aluminum. No mining has been done in these fields for over a year, since it has been found more economical to supply the demand for phosphate from the richer deposits of Tennessee.

The mining of Arkansas phosphate was conducted in a manner similar to the mining of Tennessee blue-rock phosphate, and the cost of extracting it was approximately the same.

KENTUCKY PHOSPHATE.

Several small deposits of high-grade phosphate rock have been found in the Ordovician limestone in Woodford, Scott, Fayette, and Jessamine Counties, Ky.

The phosphate occurs in thin, close-grained plates, brownish gray in color, and resembles closely the brown-rock phosphate of Tennessee. In order to prepare a high-grade product, the material must be put through a washing process like that employed in the brown-rock fields. The cleaned product varies in its content of tricalcium phosphate from 60 to 75 per cent.

A small amount of development work has been done and a small tonnage shipped from Midway, a little town on the Louisville & Nashville Railroad between Frankfort and Lexington, Ky. So far all the rock sold has been finely ground for direct application to the field.

FORMS IN WHICH PHOSPHORIC ACID IS APPLIED TO SOILS.

There are at present three broad classes of phosphatic fertilizers on the market, namely, water-soluble phosphates, phosphates which are not soluble to any extent in water but dissolve in a solution of ammonium citrate, citric acid, or some other organic solvent, and finally, phosphates which are practically insoluble in the mediums mentioned, but are supposed to yield under proper conditions a phosphatic solution sufficiently strong to produce a marked effect on the crops thus fertilized.

The form in which the first of these classes is usually applied is as monocalcium phosphate, better known as "acid phosphate" or "superphosphate," which is produced by the action of a mineral acid (usually sulphuric) upon phosphate rock. Besides soluble calcium phosphate, however, there are other well-known soluble salts of phosphoric acid, though these are used to a very small extent as fertilizers.

To the second class of phosphates belongs chiefly basic slag, a by-product of the steel industry. Finely ground steamed bone also yields part of its phosphate content to certain organic solutions.

The third class of phosphates includes raw bones and finely ground raw phosphate rock, both of which are quite resistant to the solvent action of the mediums mentioned.

By far the most extensively used of these three classes of phosphates is the water-soluble class, but large tonnages of basic slag are annually consumed for agricultural purposes, particularly in European countries. Most of the acid phosphate produced contains a considerable percentage of "reverted" (so-called) phosphoric acid, which is not soluble in water, but dissolves in ammonium citrate solution.

Because of the undoubted agricultural availability of the phosphoric acid of basic slag, bones, dicalcium phosphate, etc., it has become customary to regard phosphates which are soluble in certain organic mediums as having a fertilizer value nearly equal to that of water-soluble phosphate. Such phosphates therefore are known as available phosphates.

PROCESSES FOR TREATING PHOSPHATE ROCK IN THE MANUFACTURE OF PHOSPHORIC ACID AND PHOSPHATIC FERTILIZERS.

Numerous processes have been proposed and patented for the production of soluble or available phosphoric acid. The claims made for some of these processes are not justified, while many other processes are entirely impractical from a commercial standpoint. Much unnecessary labor has been expended in repeating experiments and in devising processes and apparatus already invented, when a thorough acquaintance with existing methods would have saved both time and money. It is thought, therefore, that classified lists

of the processes devised for the manufacture of phosphatic fertilizers arranged in chronological order, and giving short abstracts of the processes or apparatus employed, the treatment proposed, and the results or new features claimed by the inventors, will aid materially those engaged in researches of this character.

It is impossible in an article of this kind to give more than the briefest abstracts or mention of most of the numerous processes on this subject, but those are described more fully which appear to possess features particularly interesting from either a commercial or scientific standpoint.

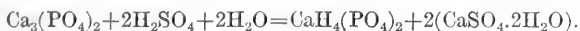
For convenience these various methods for treating phosphate rock may be classified as follows:

- (1) Acid treatment, which includes the manufacture of superphosphate and phosphoric acid; (2) combined heating and acid treatment; (3) double decomposition by means of a silicate or an alkali; (4) processes used in connection with the steel industry; (5) processes in which the phosphorus or phosphoric acid is volatilized; (6) treatment dealing with the production of two or more fertilizer elements; (7) electrolysis; (8) enrichment or concentration of phosphates; (9) processes and apparatus for the mechanical treatment of phosphates; (10) miscellaneous processes.

ACID TREATMENT.

The production of water-soluble phosphates by the treatment of phosphate rock or bones with sulphuric acid is the oldest and most widely used process. Nitric acid and hydrochloric acid have been tried in place of sulphuric, but the latter has proved itself the most satisfactory, because the calcium sulphate formed is not only a dehydrating agent, but is also only sparingly soluble in dilute solutions of phosphoric acid.

In making superphosphate, ordinary chamber acid (50° B.) and ground phosphate rock are thoroughly mixed in equal proportions by weight and the mass allowed to cure for 24 to 36 hours. The equation showing the reactions in simplest form may be represented thus:

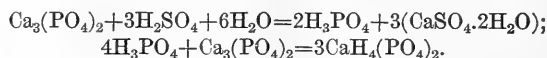


In this case the gypsum formed renders the material dry and pulverulent, and in excellent mechanical condition for mixing with other ingredients in making a complete fertilizer.

The richest superphosphate which can be made, however, by a single acid treatment of the highest grade phosphate mined in the United States (Florida hard rock) contains about 18 per cent of phosphoric acid (P_2O_5). The remaining 82 per cent consists of gypsum, siliceous material, and other impurities. It is obvious therefore, that it is poor economic policy to ship such material long

distances. In order to produce a more concentrated phosphatic fertilizer, the following method is employed:

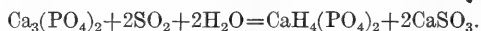
The ground phosphate rock is mixed with dilute sulphuric acid, and the phosphoric acid thus produced is separated from the gypsum and impurities both by decantation and filtration. The acid is then concentrated by evaporation and sold as such or used to treat another batch of phosphate rock in the production of double acid phosphate, which contains as high as 40 per cent of phosphoric acid (P_2O_5). The equations showing these reactions may be represented thus:



A list of the patents on this subject, arranged in chronological order, is given in Table III, Appendix.

Several of the processes cited in Table III, if they accomplish what is claimed for them, should make it possible to produce soluble phosphate more cheaply than by the methods now generally used, or to produce a more concentrated fertilizer, which will admit of shipping it long distances. The following processes have features of interest from either a scientific or an economic standpoint.

The process of Designolle¹ consists in treating phosphate rock suspended in water with sulphur dioxide under pressure, producing thereby a solution of monocalcium phosphate and sulphite of lime—thus:



The suspended matter is allowed to settle in some suitable vessel and the solution is boiled with steam to drive off the excess of sulphur dioxide and to precipitate the calcium sulphite. The solution of monocalcium phosphate is then poured off, evaporated to a sirupy consistency, and treated with plaster of Paris to take up the excess of water.

Bergmann² claims that dicalcium phosphate free from calcium sulphite is obtained by first mixing phosphate rock with sulphurous acid in the cold, then adding monocalcium phosphate to the solution, and finally boiling the solution to precipitate the dicalcium phosphate and drive off sulphur dioxide.

In the process of Machalske,³ phosphate rock is subjected to the action of sulphur dioxide in a small quantity of water. The resulting mass is leached with a dilute solution of sulphur dioxide to extract the soluble phosphates, and the residue, which is said to contain a large percentage of calcium sulphite, is calcined to recover the sulphur dioxide, which can be used again.

¹ United States Patent No. 196881 (1877).

² United States Patent No. 852371 (1907).

³ United States Patent No. 902425 (1908).

Processes of this type, if practicable, would have an advantage over the one now generally employed in that they produce available phosphoric acid from phosphate rock in a single operation, thus obviating the necessity of first manufacturing sulphuric acid. Experiments in the laboratories of the Bureau of Soils have shown, however, that phosphate rock is very resistant to the action of sulphurous acid or sulphur dioxide, and efforts to obtain complete decomposition of phosphate rock by such treatments were unsuccessful. Further work along these lines, however, seems desirable.

The processes of Glaser¹ have for their object the production of concentrated phosphates by treating phosphate rock with sufficient dilute sulphuric acid to produce phosphoric acid and then using this phosphoric acid as a solvent for more phosphate rock.

They involve the well-known method of making double acid phosphate, a method admirably suited for the treatment of low-grade phosphate rock containing but little iron and aluminum. The equations showing the reactions taking place in this process have already been shown on page 10. The product usually requires artificial drying, since it contains but little sulphate of lime. The patents of Glaser have now expired.

In order to produce a dry pulverulent product, Memminger² proposes to mix calcium fluoride or fluorite with phosphate rock and then treat the mixture with sulphuric acid. The generation of gaseous compounds of fluorine, he claims, renders the acid phosphate porous and thus facilitates the escape of moisture from the hot mass.

While this procedure would no doubt produce a high-grade acid phosphate, the poisonous nature of the fumes evolved during the curing of the acid phosphate would make it objectionable to employ such a method either in the vicinity of towns or in a farming country. Moreover, it is questionable whether the extra quantity of acid required to act upon the fluorite would not offset the advantages gained. This patent expired in 1908.

Hoyerman³ devised a process to economize on the quantity of acid required to produce available phosphoric acid. His process consists in adding to phosphate rock a quantity of sulphuric acid sufficient only to convert it into dicalcium phosphate, a product which has practically the same trade value as monocalcium phosphate.

Such a process, while theoretically possible, presents difficulties in actual practice. The quantity of ordinary sulphuric acid required is hardly sufficient to mix intimately with a large bulk of ground phosphate, and, therefore, the resulting mass is apt to contain a considerable percentage of so-called unavailable phosphoric acid, owing to the fact that some of the phosphate rock has not been acted upon.

¹ United States Patents Nos. 389596 (1888), 417820 (1889), 459575 (1891).

² United States Patent No. 445567 (1891).

³ United States Patent No. 736730 (1903).

The processes of Schlutius¹ and Bretteville,² in which nitric acid is employed as a solvent instead of sulphuric acid, are of interest because calcium nitrate and soluble calcium phosphate are produced, both of which are fertilizer materials.



Such a mixture is sufficiently high grade to stand the expense of long shipment, but the well-known hygroscopic properties of calcium nitrate form a drawback to its use in fertilizers and would probably necessitate shipping the material in air-tight containers.

PROCESSES FOR THE PRODUCTION OF PHOSPHORIC ACID OR SOLUBLE PHOSPHATES BY COMBINED HEATING AND ACID TREATMENT.

In general, these processes are not very promising, since they involve both acid treatment and the expense of heating the product. A list of the patents under this head is given in Table IV, Appendix.

The process of Scribner³ appears to be of much interest. It consists in either roasting a mixture of phosphate rock and sulphur or passing sulphur dioxide over highly heated phosphate rock. In either case it is claimed that citrate-soluble phosphate results.

This scheme is similar to two described under "Acid treatment." If it accomplishes what is claimed, much unnecessary time and expense may be saved in the manufacture of available phosphates. From the experience in the Bureau of Soils laboratories, however, it would seem rather difficult to conduct this process so as to effect the complete conversion of the phosphoric acid into an available form.

This patent expired in 1900.

DOUBLE DECOMPOSITION BY MEANS OF AN ALKALI, AN ALKALI SALT, OR ALKALINE EARTH.

All the processes under this head except four depend on heat to effect the conversion of insoluble phosphate into a water-soluble or citric-soluble form. In Table V, Appendix, a list of the various patents on this subject is given.

The object of the processes described below is to obtain a neutral or alkaline product containing available phosphoric acid. Owing to the acid properties of superphosphate there exists among certain farmers considerable prejudice against its use. Fertilizers of the type described below have, as a rule, an alkaline reaction, and therefore are popularly believed to counteract any acidity in the soil.

In the process of Commins,⁴ phosphate rock is either heated to redness and then saturated with a solution of sodium chloride or first treated with the salt solution, heated, and then plunged into gas-house liquor. In the more recent process of Lowman,⁵ a mixture

¹ United States Patent No. 872757 (1907).

² United States Patent No. 1011909 (1911).

³ United States Patent No. 283426 (1883).

⁴ United States Patents Nos. 74799, 78061 (1868).

⁵ United States Patent, No. 922494 (1909).

of phosphate rock, sodium chloride, dolomite, and fluorite is made into a paste with water and then baked for 12 hours at 700° F. The inventor claims that citrate-soluble phosphoric acid results, but states that he does not know what reactions take place.

Considering the materials used, however, it is probable that a more basic phosphate containing both lime and sodium is formed on heating such a mixture.

Day's¹ process consists in heating (with or without a potash salt) a natural or artificial mixture of phosphate rock, silica, and limestone to a temperature just above that at which carbon dioxide is driven off. He claims that the resulting product contains phosphoric acid soluble in a 5 per cent solution of citric acid. The length of time of heating required varies between rather wide limits, depending on the materials used and the thoroughness with which they are mixed.

Rocour,² Newberry and Barrett,³ Meriwether,⁴ and Landis⁵ have devised processes in which double decomposition is brought about by heating a mixture of phosphate rock and sodium sulphate; or phosphate rock, lime, and sodium sulphate. Probably the process under this head which has attracted the most attention is that of Newberry and Barrett. It is understood that the process as worked on a commercial scale differs somewhat from that described in the original patent, but the general plan consists in submitting an intimate mixture of phosphate rock and sodium sulphate to a constantly increasing temperature till a temperature of about 2,800° F. is reached. The clinker formed is then ground, sacked, and sold on the basis of the citrate-soluble phosphoric acid which it contains. It is also said that the final product contains a considerably higher percentage of phosphoric acid than the original mixture, owing to the volatilization of some of the products formed at the high temperatures.

While the reagents required (sodium chloride, sodium sulphate, etc.) to convert phosphate rock into a citrate-soluble form in such processes are comparatively cheap, the expense of maintaining the necessary high temperatures for protracted periods adds considerably to the cost of production. It is claimed, however, that in some of these processes the cost of phosphoric acid per unit is less than it is in acid phosphate.

In order to utilize low-grade phosphates unfit for acid treatment, Wiborgh,⁶ Connor,⁷ Newberry,⁸ and Galt⁹ have devised processes in which ground phosphate is mixed with an alkali hydroxide or car-

¹ United States Patent No. 542080 (1895).

² United States Patent No. 284674 (1883).

³ United States Patent No. 1042588 (1912).

⁴ United States Patent No. 1058249 (1913).

⁵ United States Patent No. 1094857 (1914).

⁶ United States Patent No. 601089 (1898).

⁷ United States Patents Nos. 931846 (1909).
1042400, 1042401 (1912).

⁸ United States Patent No. 978193 (1910).

⁹ United States Patent No. 1016989 (1912).

bonate and the mixture heated in a suitable furnace to a bright-red or yellow heat. Newberry also employs lime or limestone in his mix, and Galt uses "lime mud" (a mixture of calcium carbonate and sodium hydroxide), a by-product of the soda industry.

While these processes have not been thoroughly tested in this laboratory a conversion of at least a portion of the phosphate into a citrate-soluble form can undoubtedly be effected by such treatments. The proportions of alkali, lime, and phosphate rock required are such that the resulting product contains a much higher percentage of phosphoric acid than ordinary acid phosphate. For the commercial success of such processes, however, it must be borne in mind that the cost of heating plus the price of the reagents used in the production of a unit of phosphoric acid must not exceed the cost of the sulphuric acid required to produce a unit of phosphoric acid in superphosphates. Payne,¹ in discussing calcination processes, places the cost of available phosphoric acid produced by such processes at about 24 cents per unit.

PROCESSES TO BE USED IN CONNECTION WITH THE IRON AND STEEL INDUSTRIES.

Processes under this head have to do chiefly with the production of tetracalcium phosphate or some other basic phosphate soluble in a 2 per cent solution of citric acid. Because of the high temperature required, these processes can hardly be employed economically except in connection with the smelting industry. A list of the patents dealing with the production of available phosphoric acid along these lines is given in Table VI, Appendix.

In 1884 Thomas² devised a process for producing an alkaline phosphate from pig iron high in phosphorus. His plan consists in pouring the molten metal upon an alkali carbonate in a basic Bessemer converter. The resulting slag contains, according to his claim, phosphates of soda which can be separated by lixiviating the mass with water. This patent expired in 1901.

The processes of Reese³ are also worthy of consideration.

One of his processes consists in adding to the usual furnace charge a certain quantity of phosphate rock to enhance the value of the resulting slag. Another of his processes consists in dephosphatizing the iron or iron ore in two stages. In this way the first slag run-off contains a high percentage of available phosphate. In a third process phosphate rock and basic open-hearth slag are fused together, resulting in the production of available phosphoric acid. If this claim is borne out in actual practice it should be economically

¹ Available phosphates by furnace treatment. Amer. Fertilizer Handbook, pp. 62-64 (1914).

² United States Patent No. 301407 (1884).

³ United States Patents Nos. 412792; 412793 (1889); 714331 (1902).

practicable to manufacture the product by mixing the phosphate rock with the molten slag as the latter flows from the furnace. The heat of the slag could thus be utilized.

The fertilizer value of basic (phosphatic) slag is unquestioned, and it would be practicable to produce large quantities of this material by using phosphatic limestone to smelt siliceous iron ores, but it would be very difficult to overcome the prejudice against using a phosphorus-bearing substance in smelting operations when the chief aim is to eliminate phosphorus from the metal product.

PROCESSES IN WHICH THE PHOSPHORUS OR PHOSPHORIC ACID IS VOLATILIZED.

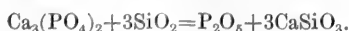
Processes under this head have been exciting considerable interest in recent years. They are all based on the method long in use for the manufacture of phosphorus and require a high temperature and a furnace which will resist both the temperature and the corrosive effect of the volatile products formed. The main advantage of the processes listed in Table VII is that comparatively pure concentrated phosphoric acid can be obtained from rather impure raw materials.

The first recorded American process for obtaining phosphoric acid in this way is that of Giles and Shearer.¹ Their process of separating phosphoric acid from its impurities consists in passing a current of steam over the acid heated to redness. The distillate condensed and collected in some suitable vessel consists of relatively pure phosphoric acid.

In 1907 Landis² described a process for producing phosphoric acid and phosphorus from phosphate rock, which consists in mixing phosphate rock, sand, or a silicate and coke with some binding material, and molding the mixture into briquettes. The briquettes are subsequently placed in an electric furnace and heated. The inventor claims that by this method a more even distribution of the heat is obtained, excessive temperatures can be avoided, and less dust and impurities are carried over with the volatilized phosphoric acid.

The methods of Levi,³ Washburn,⁴ and Haff⁵ are three of the more recent processes for the production of phosphoric acid by volatilization. Described in brief, they are as follows:

Levi heats a mixture of phosphate rock and silica or silicate in an electric furnace, claiming that the following reaction takes place:



The phosphoric anhydride which is volatilized is then absorbed in water, producing phosphoric acid (H_3PO_4), and the fused calcium

¹ United States Patent No. 393428 (1888).

⁴ United States Patents Nos. 1047864 (1912); 1100639 (1914).

² United States Patent No. 859086 (1907).

⁵ United States Patent No. 1084856 (1914).

³ United States Patent No. 984769 (1912).

silicate which remains in the furnace may be converted into a soluble silicate by the addition of an anhydrous salt of potash or soda.

Levi states that it is preferable to have a furnace of such a type that the reacting mass is not in contact with the carbon electrodes, so that the phosphoric acid formed will not be reduced to phosphorus.

Washburn, on the other hand, states that he has carried on experiments like the above on a large scale and claims that unless a reducing agent, such as carbon, be added to the mixture of phosphate rock and silica, the volatilization of phosphoric acid is very incomplete. He heats a mixture of phosphate rock, silica, and carbon until the mass is entirely fused and the phosphorus driven off as such, and also in the form of oxide. He then exposes the gases to an oxidizing atmosphere and converts any phosphorus present to phosphoric anhydride and subsequently to phosphoric acid. He claims that under the proper conditions 90 per cent of the phosphoric acid present in the rock is volatilized.

In a more recent patent, Haff describes a process very similar to the above, but states that pieces of broken carbon should be placed on the bath to form a conducting path of increased current density between the electrodes and thus allow of a higher temperature in the furnace.

Another process of Haff's,¹ as well as a patent taken out jointly by Wilson and Haff,² might be included in the subsequent table dealing with processes for the production of two or more fertilizer elements, but since they depend on the volatilization of phosphoric acid they are placed under this head. In these processes a mixture of phosphate rock and feldspar is heated in an electric furnace to a temperature at which both the phosphoric acid and the potash are driven off. The products are then condensed and collected in some suitable manner.

It is generally conceded that cheap hydroelectric power is essential for the commercial success of any of these processes. At present the demand for hydroelectric energy is so great that in any of the localities where it has been developed so far it brings a higher price than can possibly be paid for power in the economic production of phosphatic fertilizers. The enormous energy that can be developed at certain sites, as, for instance, on the St. Lawrence and the Saguenay Rivers in Canada and on the Columbia River in Oregon, energy which, owing to the distance of the power sites from large industrial centers, can not be absorbed through the usual channels, may in the future cause a revolution in the fertilizer industry by making it feasible to produce concentrated phosphates from relatively low-grade materials at considerably less cost than is possible by methods now in general use.

¹ United States Patent No. 1018186 (1912).

² United States Patent No. 1103910 (1914).

PROCESSES DEALING WITH THE PRODUCTION OF TWO OR MORE FERTILIZER ELEMENTS.

At first glance these methods appear particularly attractive from an economic standpoint, because two or more salable products are obtained by a single operation. Two of the seemingly very promising processes, however, on being tested in the laboratory proved to be commercially impracticable. A complete list of the processes under this head is given in Table VIII, Appendix.

The processes of Bickell ¹ and Klett ² deal with the production of soluble phosphoric acid and potash from phosphate rock and feldspar.

Bickell's process consists in heating in a reverberatory furnace to a light redness for two hours an intimate mixture of 1 part feldspar, 0.5 part phosphate rock, and 3 or 4 parts of lime. It is claimed that both phosphoric acid and potash in available forms are obtained by this treatment.

On testing this process in the laboratory it was found that Bickell's claim was not substantiated, for over 44 per cent of the potash present in the mixture was volatilized upon ignition, and of that which remained in the residue only 9 per cent was water-soluble. While none of the phosphoric acid was volatilized, less than 39 per cent of it was soluble in a 2 per cent solution of citric acid.

Klett's process is similar to that of Bickell and consists in heating to redness for five hours an intimate mixture of 2 parts carbonate of lime, 1 part phosphate rock, and adding for each part of potash (K_2O) in the feldspar 2 parts of calcium fluoride. It is claimed that a soluble silicate of lime and potassium phosphate are thus obtained.

In view of the fact that the percentage of potash in the mixture is relatively small and that the time of heating is very long, it is hardly likely that the value of the product would cover the cost of manufacture. Moreover, the claim that phosphate of potash is formed in the operation is not justified.

The process, however, was tried out on a laboratory scale and results obtained similar to those found in repeating Bickell's method. Nearly all of the potash was volatilized, while less than one-half of the phosphoric acid present in the residue was citric-soluble.

Both the patents of Bickell and Klett have long ago expired.

The processes of McDougall,³ Terne,⁴ Washburn,⁵ and Wilson and Haff⁶ all deal with the neutralization of the acid in superphosphate by means of ammonia, producing thereby a mixture of gypsum, ammonium sulphate, and calcium ammonium phosphate. These

¹ United States Patent No. 16111 (1856).

² United States Patent No. 49891 (1865).

³ United States Patent No. 135995 (1873).

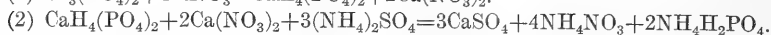
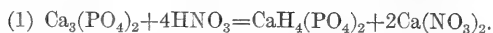
⁴ United States Patent No. 709185 (1902).

⁵ United States Patent No. 1100638 (1914).

⁶ United States Patents Nos. 1062869 (1913); 1112183 (1914); 1122183 (1914).

processes correct the acidity of the superphosphate which some farmers consider so objectionable, and at the same time enhance the value of the product.

The process of Collett¹ consists in dissolving phosphate rock in dilute nitric acid, and then adding ammonium sulphate to the solution, with the result that lime is precipitated as sulphate, and ammonium phosphate and ammonium nitrate remain in solution. After separating the gypsum, the ammonium salts may be crystallized out by concentration of the solution. The reactions may be represented thus:



This last process is particularly interesting from a commercial standpoint, since it has for its object the production of a high-grade fertilizer containing both phosphoric acid and nitrogen in readily available forms. Where phosphate rock occurs in regions far from the fertilizer markets, the production of a highly concentrated product which will admit of long shipment is essential to the successful development of the mining part of the phosphate industry.

The evaporation of the solutions, however, to the point where the ammonium salts begin to crystallize out would entail considerable expense.

PROCESSES DEALING WITH THE PRODUCTION OF AVAILABLE PHOSPHATES BY ELECTROLYSIS.

Processes under this head are of two types: (1) Those in which the phosphate rock is fused and the electric current passed through the melt; and (2) those in which some water-soluble salt or acid is used as an electrolyte and the ground phosphate rock suspended or dissolved in the solution and the electrolysis performed in the wet way. A list of the patents on this subject is given in Table IX, Appendix.

The process of Palmaer and Wiborgh² for the production of dicalcium phosphate is said to have been successfully practiced in Norway where cheap water power is available. The process is as follows:

Perchloric acid and sodium hydrate are produced by electrolyzing a solution of sodium perchlorate in a diaphragm cell. Phosphate rock is then treated with the anode solution (perchloric acid) and the resulting solution of phosphate filtered. One half of the cathode solution (sodium hydrate) is then added to this filtrate, resulting in the precipitation of dicalcium phosphate and the formation of sodium perchlorate again. The other half of the cathode solution is treated with carbon dioxide and added to the solution decanted from the dicalcium phosphate precipitate, thus precipitating the lime as carbonate and completely regenerating sodium perchlorate.

¹ United States Patent No. 1058145 (1913).

² United States Patents Nos. 707886 (1902); 748523 (1903).

The reactions taking place at various stages of the process may be represented thus:

- (1) $\text{NaClO}_4 + \text{H}_2\text{O} + \text{Electric current} = \text{HClO}_4 + \text{NaOH}$.
- (2) $6 \text{HClO}_4 + \text{Ca}_3(\text{PO}_4)_2 = 2\text{H}_3\text{PO}_4 + 3\text{Ca}(\text{ClO}_4)_2$.
- (3) $2\text{H}_3\text{PO}_4 + 3\text{Ca}(\text{ClO}_4)_2 + 4\text{NaOH} = 2\text{CaHPO}_4 + 4\text{NaClO}_4 + \text{Ca}(\text{ClO}_4)_2 + 4\text{H}_2\text{O}$.
- (4) $4\text{NaClO}_4 + \text{Ca}(\text{ClO}_4)_2 + \text{Na}_2\text{CO}_3 = 6\text{NaClO}_4 + \text{CaCO}_3$.

This process was designed to treat low-grade phosphates which are not suitable for the manufacture of acid phosphate. Cheap electric power is essential for the commercial success of the process.

PROCESSES FOR THE ENRICHMENT OF PHOSPHATES.

The list of patents given in Table X, Appendix, includes processes for the enrichment of raw or natural phosphates, as well as those which have been chemically treated.

While the writers have placed but five processes under this head, a number of patents classified under other heads could have been included here as well.

The processes of both Ottolengin¹ and Coates² have for their object the enrichment of phosphate rock or phosphatic limestone.

Ottolengin advocates the grinding of the phosphate and then effecting the separation of the phosphate particles from the impurities by the difference in their specific gravities, such a separation being made either by a blast of air or by suspending the material in moving water.

Unfortunately, in many of the natural deposits of phosphate, the impurities contained therein have a specific gravity so nearly equal to that of the phosphate rock that a separation on the above basis is usually very incomplete. In the case of the brown-rock phosphate of Tennessee, however, such a scheme is practiced with great success.

By burning, slaking, and subsequently screening phosphatic limestone Coates effects a segregation of the coarser and more phosphatic particles. This process, however, is intended primarily to produce a finely divided sterile phosphatic material for subsequent treatment.

Pratt's³ process for the enrichment of acid phosphate consists, first, in adding sufficient lime to the superphosphate to convert the monocalcium phosphate to dicalcium phosphate, then leaching out the gypsum contained therein with some suitable solvent. The solvent recommended by Pratt is sea water.

¹ United States Patent No. 86574 (1869).

² United States Patent No. 971830 (1910).

³ United States Patents Nos. 1014254, 1014255 (1912).

MECHANICAL TREATMENT OF PHOSPHATES.

The patents listed in Table XI, Appendix, deal with the mechanical treatment of either raw phosphates or the chemically treated product. The first seven processes are primarily intended for the treatment of bones or phosphates to be used in the manufacture of baking powder. The other processes listed hardly require any more detailed descriptions than those given in the tables. All the patents covering these processes have long since expired, and they can therefore be used without payment of royalties.

MISCELLANEOUS PROCESSES FOR THE PRODUCTION OF AVAILABLE PHOSPHATES.

Under the head of miscellaneous are included all the processes which can not very well be separately listed. Many of these processes are on their face practically valueless, while others have features which make it appear they might be successfully employed in the production of fertilizers of some value. A list of the patents under this head is given in Table XII, Appendix.

The process in the above table which has probably attracted the most attention is that of Coates,¹ in which the inventor claims to produce available phosphoric acid and potash from minerals containing these elements by the action of bacteria, which attack and break down the rocks. His process consists in first obtaining a culture by adding breaking-down or decaying rock to a sterilized culture medium. He then inoculates sterilized phosphate rock or feldspar with the culture thus prepared, with the result that the bacteria attack the rock minerals, rendering the phosphoric acid and potash contained therein soluble in the soil solution.

It is understood that field experiments are being conducted to test the fertilizer value of rock treated in this way, but the results of these experiments have not yet been reported.

¹ United States Patent No. 947795 (1910).

APPENDIX.

TABLE III.—Processes for the production of soluble or available phosphates by acid treatment.

Patent No.	Date.	Patentee.	Reagents used.	Treatment.	Object of process.
16882	1857	Reid, L.	Bone dust, H_2SO_4 , liquid manure, absorbents.	The various ingredients are thoroughly mixed with sulphuric acid and allowed to cure.	Production of phosphate nitrogenous fertilizer.
34825	1862	Gallicher, J. M.	Bone black (100), H_2SO_4 (46), liquid animal matter (9).	The various ingredients are thoroughly mixed and allowed to cure.	Do.
38040	1863	Gale, L. D.	Phosphate guano animal matter, H_2SO_4 .	do.....	Production of concentrated manure.
41428	1864	Harper, L.	Guano, liquid animal matter, H_2SO_4 , alkaline salts.	Part of guano is mixed with liquid animal matter, part with H_2SO_4 , alkaline salts are added, and the whole thoroughly mixed.	To improve or enrich guano.
41663	1864	Hayes, A. A.	Guano, NaCl , H_2SO_4 , animal matter.	Ingredients are thoroughly mixed and allowed to cure.	To restore guano.
42006	1864	Liebig, G. A.	Navassa guano, H_2SO_4 .	The coarse particles of guano are separated from the fine and each part treated separately with H_2SO_4 .	To separate and treat guano.
46700	1865	Potts, R. B.	do.....	The guano is sprinkled with H_2SO_4 .	The production of dry pulverulent product.
49831	1865	Liebig, G. A.	Navassa guano, HCl or SO_2 .	Either HCl or a solution of SO_2 is substituted for H_2SO_4 in the making of acid phosphate.	To use some other mineral acid.
59978	1866	Figamier, A. de.	Phosphate rock, H_2SO_4 .	Phosphate rock and H_2SO_4 are mixed in a special machine.	Improved product due to efficient mixing.
75271	1868	Horsford, E. N.	(Tribasic phosphate of lime, HNO_3 , H_2SO_4 ,	$\text{Ca}_3(\text{PO}_4)_2$ is dissolved in HNO_3 . H_2SO_4 is added and CaSO_4 thus precipitated. HNO_3 is driven off by heat.	To produce pulverulent acid phosphate.
75272	1868	Wilson, Geo. F.	Bone or its derivatives, niter cake or salt cake, water, steam.	Bones, water, and hot niter cake, salt cake, or both, are placed in a revolving cylinder, and steam is led into the mixture under high pressure.	Production of fertilizer material and distillation of HNO_3 or HCl .
75327	1868	do.....	Bones, steam, water, H_2SO_4 . Bone charcoal.	Diluted sulphuric acid is first heated in a lead-lined vat, heated by a steam coil, bones and bone charcoal are then added.	Production of CaSO_4 , $\text{CaH}_2(\text{PO}_4)_2$, and $(\text{NH}_4)_2\text{H}_2(\text{PO}_4)_2$.
75336	1868	Wilson, G. F. and Horsford, E. N.	$\text{CaH}_2(\text{PO}_4)_2$, H_2SO_4 , burned bone	Ingredients are mixed and product is leached.	Production of acid phosphate.
75338	1868	do.....	Bones H_2SO_4 .	do.....	Do.
75339	1868	do.....	Phosphate rock, HCl or HNO_3 purified	H_2SO_4 is purified and then added to solution of phosphate dissolved in HNO_3 .	Production of pure acid phosphate.
76763	1868	Horsford, E. N.	HNO_3 , H_2SO_4 , bones.	H_2SO_4 is added to solution of bones in HNO_3 .	Do.
86289	1869	Duvail, A.	Phosphate rock, steam, H_2SO_4 .	Phosphate rock and H_2SO_4 are mixed by means of steam or by air blast.	Improved method of mixing acid and rock.
90367	1869	Labor, Wm.	H_2SO_4 from refining of petroleum phosphate rock.	Ingredients are thoroughly mixed and product is allowed to cure.	Utilization of waste acid and production of acid phosphate.
113416	1871	Forbes & Paston.	Sewage, phosphate rock, H_2SO_4 , CaCO_3 .	Phosphate rock is acidulated and product treated with sewage.	Improvement in treatment of sewage and production of fertilizer.
125613	1872	Pratt, N. A.	Phosphate rock, slaked lime, H_2SO_4 .	Phosphate rock is acidulated and then passed through filter press. Filtrate is then mixed with slaked lime.	Production of two cakes of fertilizer.

TABLE III.—Processes for the production of soluble or available phosphates by acid treatment—Continued.

Patent No.	Date.	Patentee.	Reagents used.	Treatment.	Object of process.
128904	1872	Pratt, N. A.	Phosphate rock, H_2SO_4 , lime.	H_2SO_4 is mixed with phosphate rock while grinding the latter. Bags are filled with product and pressed lime is added to material coming through bags.	Improvement in treating phosphate rock.
128752	1872	Pratt & Lewis.	Phosphate rock, H_2SO_4 .	H_2SO_4 is mixed with product and soluble P_2O_5 pressed out. Fertilizer salts are added to extract and whole evaporated. Burned bones are treated in two charges, the first with H_2SO_4 and the second with HCl. The solutions resulting are mixed and evaporated and taken up with starch.	Production of fertilizer and method of making same.
130298	1872	Horsford, E. N.	Burned bones, H_2SO_4 , water, bone coal, HCl, heat, air, starch.	Phosphate rock is converted into H_2PO_4 by H_2SO_4 . Solution is drawn off and treated with $Ba(OH)_2$. This is filtered and the solution used to produce any desired phosphate.	Production of acid phosphate and absorption of same.
137635	1873	Storek, H., and Lyte, F. M.	Phosphate rock, H_2SO_4 , $Ba(OH)_2$ or other convenient form of barium.	Phosphate rock is treated with water saturated with CO_2 . Ingredients are thoroughly mixed and allowed to cure.	Production of H_3PO_4 or phosphates free from lime and sulphates.
140559	1873	Tanner, Benj.	Phosphate rock, H_3PO_4 , lime.	Phosphate rock is dissolved by SO_2 under pressure, sulphite of lime separated, and SO_2 driven off from solution by heat. Resulting acid phosphate can be treated as desired.	Production of acid phosphate of lime.
164457	1875	Jas. A.	Phosphate rock, Cl_2 , water.	Ingredients are thoroughly mixed and allowed to cure.	Production of H_3PO_4 .
173621	1876	Griffith, A. G.	Bone dust, guano, manure, H_2SO_4 .	Phosphate rock, SO_2 (under pressure), plaster of paris, heat.	Improved fertilizer.
196881	1877	Designolle, G. L. G.	Ground bone, H_2SO_4 , CaO .	The blast furnace slag is thoroughly sprinkled with H_2SO_4 .	Production of acid phosphate and drying same with plaster of paris.
211238	1879	Jugmanson, Jonas.	Slag (blast furnace), H_2SO_4 .	Ingredients mixed and allowed to cure.	Production of available P_2O_5 .
235240	1881	Lippincott & Lippincott.	Phosphates of iron and aluminum, H_2SO_4 .	The blast furnace slag is thoroughly sprinkled with H_2SO_4 .	Production of phosphate fertilizer.
276143	1883	Knight, J. J.	Phosphates of iron and aluminum, H_2SO_4 .	Ingredients are thoroughly mixed and acid extract filtered.	Production of H_3PO_4 .
278383	1883	Young, J. K.	Phosphate rock, night soil, H_2SO_4 .	Ingredients are mixed, dried, and pulverized.	Production of improved fertilizer.
278480	1883	do.	Guano, night soil, H_2SO_4 .	do.	do.
279445	1883	Scribner, Carl.	Basic slag, HCl, lime.	Slag is first roasted, then treated with HCl. Milk of lime is then added to the solution.	Production of precipitate containing available P_2O_5 .
281635	1883	Koefoed, A. H.	Iron or aluminum phosphate, lime or dolomite, acid.	Ingredients are ground, mixed, calcined, and treated with a mineral acid (H_2SO_4 , HNO_3 , or HCl).	Production of soluble P_2O_5 .
283427	1883	Scribner, E. A.	Iron or aluminum phosphate, SO_3 , steam.	Steam and SO_3 are passed through the heated pulverized phosphate.	Production of available P_2O_5 .
301248	1884	Liebig, G., and Gibbons, J. F.	Phosphates containing iron or aluminum, or both, dilute H_2SO_4 .	The phosphates and acid are thoroughly mixed and the resulting solution heated.	Production of soluble P_2O_5 .
302666	1884	do.	Phosphates of iron or aluminum, dilute H_2SO_4 , other salts.	The phosphate and acid are thoroughly mixed, the solution filtered, dried, and other fertilizer salts are added.	Production of dry fertilizer containing P_2O_5 and other fertilizer elements.
305249	1884	Stillman & Koefoed.	Iron and aluminum phosphates, dolomite, H_2SO_4 .	The phosphates and dolomite are mixed and calcined, then treated with H_2SO_4 .	Production of phosphate which does not readily revert.
322698	1885	Dibben & Dubbs.	Solution of $HNaSO_4$, phosphate rock.	The $NaHSO_4$ is dissolved in hot water and the solution used to decompose phosphate rock.	Production of soluble phosphate.
389566	1888	Glaser, Chas.	Mineral phosphate, H_3PO_4 .	Phosphate rock is dissolved in H_2PO_4 . The resulting solution is used to treat a fresh batch of phosphate rock.	Production of concentrated phosphate fertilizer.

407240	1880	Powder, N.....	Redonda phosphates, animal matter, H_2SO_4	Ingredients are thoroughly mixed and allowed to cure.....	Production of improved fer-tilizer.
407241	1880	do.....	Guano, animal matter, H_2SO_4 , $CaCO_3$	Ingredients are mixed thoroughly and allowed to cure.....	Production of an improved dry fertilizer.
417820	1880	Glaser, Chas.....	Phosphate rock, H_3PO_4	Finely ground phosphate rock is treated with H_3PO_4 and allowed to cure.	Production of double acid phosphate.
418230	1880	Winssinger, C. E. D....	Phosphate of lime, H_2SO_4 , Na_2SO_4 , lime, heat.	Acid phosphate or H_3PO_4 is produced by the action of H_2SO_4 on $Ca_3(PO_4)_2$. The solution is treated with Na_2SO_4 , giving NaH_2PO_4 . Addition of Na_2CO_3 gives Na_2HPO_4 and precipitates iron and alumina, which is filtered off. Milk of lime is then added to the solution and the whole filtered.	Production of precipitated phosphates of iron alumina, caustic soda, and precipitated lime phosphate.
443255	1891	Seal, Wm. B.....	Phosphate rock, H_2SO_4 , coal dust, animal matter.	Ingredients are thoroughly mixed and allowed to cool.....	Production of improved fertilizer.
443567	1891	Memminger, A.....	Phosphate rock, CaF_2 , H_2SO_4	Phosphate rock and CaF_2 are ground intimately together and the mixture treated with H_2SO_4 .	Production of dry acid phosphate.
459575	1891	Glaser, Chas.....	Phosphate material, dilute H_2SO_4	Phosphate material mixed with dilute H_2SO_4 . Solution of H_2PO_4 resulting is used to dilute more H_2SO_4 , and the mixture of acid is used to treat more phosphate rock.	Production of H_3PO_4 of growing strength without evaporation.
494940	1893	Riesmüller, Ludwig....	Phosphate rock or bones, organic matter, H_2SO_4	Organic matter is dissolved in H_2SO_4 , fat is skimmed off, and phosphate rock or bones added.	Production of improved fertilizer.
496687	1893	Hoffman, P. C.....	Phosphate rock, H_2SO_4 , external heat..	Ingredients mixed in the usual way and heated.....	Rapid production of soluble phosphate.
504453	1893	Meyer, Theo.....	Na_2SO_4 , H_3PO_4 , $CaCO_3$	Na_2SO_4 is dissolved in H_3PO_4 . $CaCO_3$ is added to solution.....	Production of phosphatic fertilizer from spent bone black.
515708	1894	Gregory, John.....	Bone black from oil purification, H_2SO_4	Ingredients thoroughly mixed and boiled. Grease is skimmed off.	Production of double acid phosphates free from pyrophosphoric acid.
631181	1899	Schüler, G.....	Phosphate rock, H_3PO_4 , heat.....	Ingredients are mixed and boiled, temperature being held below $115^\circ C$. Mass is dried, ground, and sifted.	Production of concentrated phosphate.
655458	1900	Saxl, H.....	Phosphatic material, H_2SO_4 , H_2O	Phosphate is thoroughly mixed with acid and allowed to stand; product is then mixed with water and solution decanted. Solution is then used to treat more phosphate.	Production or separation of precipitated lime phosphate.
657717	1900	Wharton, J. C.....	Phosphate rock, NH_4Cl , H_2SO_4 , CO_2 , lime, heat, water.	$(NH_4)_2SO_4$ and HCl are first produced by treating NH_4Cl with H_2SO_4 . The evolved HCl is led into a mass of phosphate rock suspended in water. Phosphate solution is then filtered and evaporated and placed in a closed container into which NH_3 is led from the decomposition of $(NH_4)_2SO_4$ by lime. The lime phosphate is thus precipitated and filtered off. The solution is then treated with CO_2 , which precipitates the lime and regenerates NH_4Cl .	Production of improved fertilizer.
683014	1901	Augstadt & Cleaver....	Phosphate rock, garbage, H_2SO_4	Garbage is treated with phosphate rock at $400^\circ F$. Phosphate rock is then thoroughly mixed with product.	Production of monocalcium and dicalcium phosphates.
690048	1901	Cheeseman, Lewis....	Phosphate rock, $NaHSO_4$, H_2O , H_2SO_4 or HNO_3 , electricity.	A current of electricity is passed through the mixture.	Production of a mixture of monocalcium and dicalcium phosphates.
690049	1901	do.....	Phosphate rock, $NaHSO_4$, H_2SO_4	Phosphate rock is mixed with H_2O and sufficient H_2SO_4 to attack carbonates and fluorides in rock. $NaHSO_4$ is then added and the water removed by evaporation.	Production of improved fertilizer.
703295	1902	Newport, R. B.....	Phosphate rock, garbage, H_2SO_4	Garbage is first digested to free it from grease, then mixed with phosphate rock and H_2SO_4 .	Production of citric-soluble P_2O_5 .
736730	1903	Hoyermann, G.....	Phosphate rock (100), H_2SO_4 (30).....	Sufficient H_2SO_4 is added to convert phosphate rock to dicalcium phosphate.	

TABLE III.—Processes for the production of soluble or available phosphates by acid treatment—Continued.

Patent No.	Date.	Patentee.	Reagents used.	Treatment.	Object of process.
744128	1903	Strickler, E. H.	Phosphate rock, niter cake, carbonaceous matter.	Phosphate rock and niter cake are digested with water. The liquor is then filtered and mixed with carbon.	Production of trisodium phosphate.
852371	1907	Bergmann, E.	Phosphate rock, water, SO_2 , $\text{CaH}_4(\text{PO}_3)_2$, heat.	Phosphate rock is dissolved in cold H_2SO_4 . The solution is then boiled and CaHPO_4 precipitated. $\text{CaH}_4(\text{PO}_3)_2$ is then added to filtrate, resulting in precipitation of more CaHPO_4 .	Production of CaHPO_4 free from sulphates.
852372	1907	do.	Phosphate rock, water, SO_2 , and P_2O_5 , HCl , or H_2SO_4 .	Phosphate rock is dissolved in cold H_2SO_4 . The free SO_2 is then eliminated by boiling and a mixture of CaHPO_4 and CaSO_3 is precipitated. After separation, H_2SO_4 or some other acid is added to the precipitate.	
872757	1907	Schlutius, J.	Phosphate rock, HNO_3 , or other oxides of nitrogen.	Phosphate rock is treated with HNO_3 obtained by oxidizing atmospheric nitrogen.	Production of soluble phosphoric acid.
902425	1908	Machalske, F. J.	Phosphate rock, SO_3 , H_2O , heat.	Phosphate rock is subjected to action of SO_3 in presence of small quantity of water. Soluble material then dissolved in water saturated with SO_3 . Residue of CaSO_3 is then calcined.	Production of soluble phosphate by means of action of SO_3 on phosphate.
997968	1911	Cusatelli, G.	Phosphate rock, H_2SO_4 , HNO_3 .	Phosphate rock is treated in the usual manner with H_2SO_4 to which a small quantity of HNO_3 is added.	Production of rich phosphate fertilizer which does not readily revert.
1003681	1911	Williams, R.	Phosphate rock, H_2SO_4 , refrigeration, NH_3 .	Phosphate rock is mixed with H_2SO_4 at low temperatures so that iron and aluminum compounds are unattacked.	Economy in H_2SO_4 and production of soluble P_2O_5 .
1011909	1911	Bretteville, A.	Phosphate rock, HNO_3 , lime.	Phosphate rock is dissolved in HNO_3 . Lime is added to the solution and precipitate separated by decantation or filtration.	Production of phosphate fertilizer containing $\text{Ca}(\text{NO}_3)_2$.
1020153	1912	Newberry, S. B., and Barrett, H. N.	Phosphate rock, H_2SO_4 , HCl , heat.	Phosphate rock is treated with H_2SO_4 and HCl . The solution is filtered from the CaSO_4 and evaporated to dryness. HCl is evolved and used again.	Production of CaHPO_4 .
1034090	1912	Dunham, H. V.	Phosphate rock, H_2SO_4 , water.	Ingredients are mixed thoroughly and calcined.	Production of citric-soluble P_2O_5 .
1105304	1914	Elliott, W. R.	Phosphate rock (finely ground), H_2SO_4 .	Phosphate material is thoroughly agitated by means of an air current and simultaneously sprayed with H_2SO_4 .	Production of acid phosphate.

TABLE IV.—Processes for the production of phosphoric acid by combined acid and heat treatment.

Patent No.	Date.	Patentee.	Reagents used.	Treatment.	Object of process.
73326	1868	Wilson, G. F.	Bones, heat.	Bones are burned.	Burning puts bones into better condition for acid treatment.
283426	1883	Scribner, E. A.	Aluminum or iron phosphate, S or SO ₂ , heat.	Mixture of phosphate and S is roasted, or SO ₂ is passed through heated phosphate.	Production of available P ₂ O ₅ .
382604	1888	Goodale, S. L.	Minerals containing considerable quantities of hydrated alumina or ferric phosphate or both, carbonaceous material, H ₂ SO ₄ , heat.	Mineral is powdered and mixed with carbonaceous material previously moistened with H ₂ SO ₄ . Mass is then heated.	Production of available phosphate.
446087	1891	Ruymbeke, J. Van.	Aluminum and iron phosphates, H ₂ SO ₄ , heat.	Phosphate is treated with H ₂ SO ₄ as usual, and then heated until it assumes a gray color.	Production of a metaphosphate containing sulphate of both iron and alumina.
446998	1891	do.....	Phosphate, K ₂ SO ₄ or KCl, H ₂ SO ₄ , heat.	Phosphate is powdered, and K ₂ SO ₄ and H ₂ SO ₄ added. The mixture is then heated.	A product which is highly soluble in water, free from stickiness, and nondeliquescent.
462366	1891	Simpson, J.	Tricalcic or dicalcic phosphate, HCl, sulphate of soda, water, heat, caustic lime.	Phosphate is dissolved in HCl and a solution of sulphate of soda added. Supernatant liquor is drawn off and concentrated, the evolved HCl being condensed. The pasty liquor is now heated and then run into water. This solution contains phosphate and chloride of soda which are "salted out" separately. The phosphate of soda is dissolved and treated with caustic lime. Lime phosphate separates out and caustic soda remains in solution.	Production of caustic soda and, if desired, lime phosphate.
965028	1911	Newberry, S. B., and Barrett, H. N.	Phosphate rock, H ₂ SO ₄ , heat.	Phosphate is pulverized and mixed with H ₂ SO ₄ . Mixture is calcined in an oxidizing atmosphere. This decomposes the CaSO ₄ with liberation of SO ₂ and O. Material is then ground.	Production of a citrate-soluble material containing calcium pyrophosphate and free lime.
1024880	1912	Coates, L. R.	Native phosphates, limestone, heat, H ₂ SO ₄ .	Phosphate and limestone are powdered and mixed. The mixture is calcined and then slaked with H ₂ SO ₄ , only enough acid being used to leave the material as a dry powder.	Production of a fertilizer.

TABLE V.—Processes for the production of soluble or available phosphates by decomposition with a silicate, alkali, or alkaline earth.

Patent No.	Date.	Patentee.	Reagents used.	Treatment.	Object of process.
45961	1865	Liebig & Cooper.....	Aluminum or iron phosphate, lime, soda, or potash.	Phosphate is heated with lime. Resulting $\text{Ca}_2(\text{PO}_4)_2$ is treated with soda or potash.	Production of an alkaline phosphate.
74799	1868	Commins, John.....	Phosphate minerals, heat, solution of common salt.	Phosphate is heated and then saturated with the salt solution.....	Production of soluble phosphate.
78061	1868	do.....	NaCl solution, gas liquor, phosphate rock.	Phosphate is treated with NaCl solution, heated, and plunged into gas liquor.	Production of soluble or available P_2O_5 .
90057	1869	Stewart, David.....	Phosphate rock, potash solution, lime, gypsum.	Alternate layers of phosphate moistened with caustic potash solution and lime are composted. Gypsum may be added on battering the mixture.	Production of "the persicator."
102438	1870	Sapp, W. I.....	Phosphatic guano or bones, etc., water-glass.	Constituents are mixed.....	Production of water-soluble phosphate.
119994	1871	Prescott, D. W.....	Bone dust (1,600 pounds), soda ash (300 pounds), water (15 to 20 gallons).	Bone dust and soda ash are mixed and moistened with water. The mass is allowed to remain in a heap for about two weeks and then dried.	Production of soluble phosphate.
123743	1872	Tanner, Benjamin.....	H_2PO_4 , NaCl, heat.....	H_3PO_4 is treated with NaCl. Moisture and HCl are then evaporated off.	Production of sodium phosphate.
252029	1882	Gibbons & Liebig.....	Aluminum or iron phosphate, soda or potash salts, carbonaceous matter.	Mixture is burned and acidulated.....	Method of increasing the availability of P_2O_5 .
284674	1883	Rocour, Georges.....	Phosphatic slag, coal, Na_2SO_4	Reduce phosphate and then roast with Na_2SO_4	Production of Na_3PO_4 .
453299	1891	Glaser, Charles.....	Aluminum phosphate, alkali solution, heat, CO_2 , lime.	Phosphate is digested with alkali solution, this being promoted by heat. The resulting solution is separated from the residue and saturated with CO_2 , phosphate of alumina being precipitated. Lime is added to the remaining liquid to recover alkali.	Production of citrate-soluble phosphate.
453300	1891	do.....	Aluminum phosphate, carbonate or phosphate of an alkali, water, heat.	Finely divided phosphate is treated with solution of alkali carbonate, being heated in the meantime. Resultant solution is separated from residue and cooled, phosphate of aluminum being deposited.	Production of citrate-soluble aluminum phosphate.
542080	1895	Day, David T.....	Phosphate rock containing SiO_2 and CaCO_3 (should the rock not contain these they are added), heat, salt of an alkali.	Phosphate rock is heated to a point below fusion but above temperature of decomposition of CaCO_3 . Addition of a salt of an alkali lowers necessary temperature.	Production of citrate-soluble lime phosphate.
588266	1897	DeChalmot, G.....	Phosphate rock, electric current, sand, water.	Phosphate is crushed and fused in an electric furnace. The fused mass runs out and falls upon sand. It is then dumped into water.	Production of citrate-soluble phosphate.
589197	1897	Stead, J. E.....	Natural phosphates, siliceous and calcareous matter.	Materials are melted together.....	Phosphate soluble in solvents existing in the soil.
598182	1898	Poole, Herman.....	Native aluminum phosphate, heat, caustic soda solution, aqueous solution of sodium silicate, H_2SO_4 .	Phosphate is boiled in caustic soda solution. It is then filtered and the filtrate mixed with sodium silicate solution. Alumina is thus precipitated as silicate. The sodium phosphate remaining in solution is crystallized out. The aluminum silicate is heated with H_2SO_4 , yielding aluminum sulphate.	Production of tribasic sodium phosphate and aluminum sulphate.
601089	1898	Wiborgh, J. G.....	Apatite, carbonate of sodium or potassium or caustic soda or potash, heat.	Mixture is heated.....	Production of citrate-soluble tetracalcium sodium (or potassium) phosphate.

721489	1903	Wolters, Wilhelm.....	Phosphorites or bone, silicates of alkaline earths and alkalis, heat.	Materials are melted together.....	Production of citrate-soluble phosphate.
917582	1909	Strickler, E. H.....	NaHSO ₄ , phosphate rock, heat.	Phosphate rock is dissolved in a solution of NaHSO ₄ and Na ₂ SO ₄ crystallized out.	Process of separating Na ₂ SO ₄ from H ₃ PO ₄ .
922494	1909	Lowman, J. W.....	Phosphate rock or bones, etc., NaCl, dolomite, fluorspar, heat, water, potash.	Phosphate is pulverized, and dolomite and fluorite are burned and pulverized. All are mixed with NaCl and water. The mass is then heated. Potash is added when the phosphate rock is highly siliceous.	Production of available phosphate.
931846	1909	Connor, J. H.....	Phosphates, Na or K hydroxides or carbonates, Ca or Mg or Ba hydroxides, water, heat.	Ground phosphate is mixed with alkali, alkaline earth, and water. This mixture is heated and then ground.	Production of available phosphoric acid.
972567	1910	Newberry, S. B.....	Natural phosphates or bones, etc., phosphoric acid or water-soluble phosphates such as those of Na or K, heat.	Mixture is calcined and ground.....	Production of citrate-soluble phosphate.
978193	1910	do.....	Phosphate rock or bone, lime, soda or potash carbonate as flux, heat.	Materials are mixed, calcined, and ground.....	Do.
991096	1911	Schröder, Heinrich.....	Aluminum, iron, and calcium phosphates, Mg or Ca chlorides, water, heat, NaCl.	Phosphate and chloride are mixed and heated with exclusion of air after the principle of fractional sublimation. Above 100° C. the vapors are led into NaCl solution and aluminum sodium chloride is formed. Above 183° C. HCl is formed and condensed. Above 280° C. ferric chloride is formed, which may be decomposed into ferric oxide and HCl by steam. The residue in the furnace contains the alkali earth phosphate formed. If MgCl ₂ has been used, the phosphate formed is soluble in citrate solution. If CaCl ₂ has been used, the phosphate must be treated (HCl treatment) to render it soluble.	Do.
995894	1911	Palmer, W.....	HCl, NaOH, phosphate rock.....	Phosphate rock is dissolved in HCl and NaOH added to precipitate.	Production of citrate-soluble P ₂ O ₅ .
1002198	1911	Frerichs, F. W.....	Calcium phosphate, ammonium sulphate, heat, H ₂ SO ₄ , water.	Phosphate and ammonium sulphate are mixed and roasted. Calcium phosphate is obtained, ammonia being driven off. The pyrophosphate is treated with H ₂ SO ₄ and water, Ca(PO ₃ H ₂) ₂ and CaSO ₄ being obtained.	Production of a fertilizer.
1016352	1912	Meriwether, C. N.....	Natural phosphate, carbonate or fluoride of lime, heat, water, potash granite or magnesite.	Phosphate is mixed with the lime compound, and the mass fused. It is then run into water and ground. Potash-granite or magnesite may be added.	Do.
1016989	1912	Galt, H. A.....	Lime mud (a mixture of CaCO ₃ and NaOH obtained as a by-product in the manufacture of caustic soda), phosphate rock, heat.	Lime mud and phosphate are mixed and heated.....	Production of soluble phosphates.
1025619	1912	Giese, F., and Wolters, W.....	Natural phosphate, artificial silicates (or their raw materials, such as acid sodium sulphate, limestone, and sand), heat, steam, air.	Phosphate and artificial silicate are melted together, and the melted mass is finely distributed by a blast of mixed steam and air.	Production of citrate-soluble phosphate.
1042400	1912	Connor, J. H.....	Phosphate rock or bones, etc., limestone, soda, iron oxide (fine dust) or sodium sulphate, water, heat.	Materials are mixed, and, in a wet state, subjected to a high temperature. It is then ground.	Production of available phosphate.
1042401	1912	do.....	Phosphate rock or bones, etc., soda ash or sulphur soda ash, iron oxide (fine dust) as a flux, heat, water.	Materials are mixed and heated.....	Do.
1042402	1912	do.....	Phosphate rock or bones, etc., sodium salts, heat, water, iron oxide (fine dust).	Materials are mixed, heated, and ground.....	Do.

TABLE V.—Processes for the production of soluble or available phosphates by decomposition with a silicate, alkali, or alkaline earth—Continued.

Patent No.	Date.	Patentee.	Reagents used.	Treatment.	Object of process.
1042588	1912	Newberry, S. B., and Barrett, H. N.	Natural phosphates, alkali sulphates, water, heat.	Materials are mixed and heated in an oxidizing atmosphere. Phosphate and lime rock are mixed, ground, and heated. Mass is then run out, combined with Na and K compounds, ground, again heated, and reground. Mixture is dried and calcined. Mixture is burned while air is being blown through. Product is pulverized.	Production of citrate-soluble phosphate. Production of a fertilizer.
1068249	1913	Merliwether, C. N.	Phosphate rock, lime rock, heat, compound of Na or K, etc. Iron oxide dolomite, may be added.		
1094857	1914	Landis, W. S.	Phosphate rock, Na_2SO_4 , water.	Mixture is heated in presence of steam. Product is treated with sufficient water to cool and hydrate the same and leave a dry powder. Mixture is heated.	Production of soluble or available P_2O_5 . Production of citric-soluble phosphate.
1103059	1914	do.	Phosphate rock, Na_2SO_4 or Na_2CO_3 , water, C.		
1111490	1914	Perino, Josef	Potash, containing silicate rock, phosphate rock, MgO , heat, steam, water.		
1120917	1914	Downs, W. F.	Finely divided phosphate rock, finely divided silica, heat.		

TABLE VI.—Processes to be used in connection with the iron and steel industries for the production of soluble or available phosphates.

Patent No.	Date.	Patentee.	Reagents used.	Treatment.	Object of process.
284674	1883	Rocour, G.	Phosphatic slag, flux, lime, Na_2SO_4 , H_2SO_4 , coal or coke, pyrites, H_2O .	The slag is first fused under reducing conditions. (1) The matte is blown in a basic converter with the addition of lime and small quantities of Na_2SO_4 . (2) Matte is mixed with Na_2SO_4 and coal and heated in reverberatory furnace in reducing flame, oxidizing flame being used later. Mass is then lixiviated. The alkaline chlorides are blown into the phosphorus iron in a Bessemer converter along with steam, water gas, or other hydrogen-yielding substance. Resulting slag is lixiviated and lime added to the solution. Molten metal is poured upon an alkali carbonate in a basic Bessemer furnace. More Na_2CO_3 is introduced by the blast. The slag is then run off and lixiviated.	Methods of obtaining soluble alkaline phosphates. Production of precipitated phosphate of lime from phosphorus-bearing iron.
301406	1884	Thomas, S. G.	NaCl or KCl , iron containing over 1 per cent P, superheated steam or water gas, Fe_2O_3 , H_2O , lime, air, heat.		
301407	1884	do.	Molten pig iron containing P, Na_2CO_3 , NaNO_3 , lime, H_2O , heat.	Production of alkaline phosphate from phosphorus-bearing iron. Production of H_3PO_4 from phosphatic slag.	
306864	1884	Thomas, S. G., and Twinman, T.	Slag containing iron oxide and P_2O_5 , HCl , oxidizing agent, lime, H_2SO_4 , H_2O , heat.		
312904	1885	Scheibler, Carl	Slag (phosphatic), slow cooling.	Segregation of P_2O_5 near surface of mass. Production of Na_2HPO_4 and Na_2CO_3 .	
324471	1885	Imperatori, Luigi	Phosphatic slag, Na_2SO_4 , C, CO_2		

33825	1886	Scheibler, Carl.....	Slag (phosphatic), heat, H_2O , lime.....	The slag is roasted in oxidizing flame, ground, and treated with HCl. Milk of lime is added, fractionally precipitating (1) phosphates of iron, (2) the alkaline earth phosphates. The phosphates of iron are then again roasted with lime, giving phosphates of lime. Na 2 PO $_4$ is added to molten phosphatic pig iron, and Na 2 CO $_3$ is subsequently added. Slag is pulverized and the iron separated by magnet. The phosphatic rock is oxidized at high temperature in the presence of lime. The slag is then withdrawn and slowly cooled. A mixture of phosphatic iron and CaO is charged in basic Bessemer converter and slag withdrawn before iron is completely dephosphatized. Fresh lime is then added to charge.	Production of phosphates of lime from slags containing iron phosphates. Production of soluble P $_2$ O $_5$. Production of available P $_2$ O $_5$. Production of Ca $_2$ P $_2$ O $_7$ or available P $_2$ O $_5$. Production of highly phosphatic slag, and subsequent dephosphatization of steel. Production of tetracalcium phosphate. Production of disintegrated slag. Production of fertilizer containing available P $_2$ O $_5$. Production of two highly phosphatic slags and elimination of phosphorus from iron. Production of available P $_2$ O $_5$, which may be mixed with fertilizer salts. Production of a mixture of soluble and available P $_2$ O $_5$ and (NH $_4$) $_2$ SO $_4$.
361656	1887	Twynnam, Thos.....	Phosphatic iron, Na $_2$ PO $_4$, Na $_2$ CO $_3$	Phosphate rock and slag are mixed and fused in a furnace in presence of oxidizing flame; gases should be largely CO $_2$. Iron ore and phosphatic rock are heated in blast furnace. The slag produced is separated from iron rich in phosphorus. The iron is treated a second time with basic materials, giving another highly phosphatic slag.	
372187	1887	Reese, Jacob.....	Basic phosphatic slag, magnet.....	Phosphate rock and iron ore are intimately mixed. Mixture is then heated to redness for 1 hour to 6 hours while being agitated. Fertilizer salts may be mixed with cooled product.	
412792	1889	do.....	The usual furnace charge, with the addition of phosphatic rock.	A mixture of slag and phosphate rock is placed in a digester and steam led into mixture. The slag disintegrates. SO $_2$ is then introduced and then NH $_3$ gas.	
412793	1889	do.....	Phosphatic iron, CaO, heat.....		
535204	1895	Howe, H. M., and Stead, J. E.....	Slag, phosphate rock, a metallic base, lime, heat.	Phosphate rock is added to the molten slag in the furnace; lime is added if necessary. Slag is then run out before iron is completely dephosphorized. Slag is comminuted. Na $_2$ CO $_3$ is added to molten slag as it issues from furnace.....	
550024	1895	Meyer, Emil.....	Phosphatic slag, Na $_2$ CO $_3$		
714331	1902	Reese, Jacob.....	Phosphatic slag, phosphate rock, CO $_2$, heat.		
977819	1910	Mehner, H.....	Iron ore, phosphate rock, oxides of iron, lime, carbon, heat.		
1002297	1911	Meriwether, C. N.....	Iron ore, phosphate rock, lime, heat, salts of Ba, K, Na, NH $_4$, and Mg may be used or ferrocyanide of potash.		
1067224	1913	Slater, O. K.....	Basic slag, phosphate rock, steam, SO $_2$, NH $_3$.		

TABLE VII.—Processes for the production of phosphorus and phosphoric acid by volatilization.

Patent No.	Date.	Patentee.	Reagents used.	Treatment.	Object of process.
393428	1888	Giles, W. B., and Shearer, Arthur.	Phosphatic material, steam, heat.....	Phosphoric material is so treated as to obtain an impure phosphoric acid. This is concentrated and placed in a retort. Here it is kept at a red heat and a current of steam is passed over it. The distillate is condensed.	Process for separating phosphoric acid from impurities.
417943	1889	Readman, J. B.....	Phosphorus-yielding material in solution, carbon, a flux, electric furnace.	The phosphorus solution is concentrated and carbon incorporated. A flux may be added. It is placed in an electric furnace and phosphorus distills over.	Process of obtaining phosphorus.
452821	1891	Wing, H. H.....	Phosphate rock, siliceous material, coal or coke, heat.	Phosphate rock is ground, mixed with the siliceous material, and molded into small balls. These are placed in a furnace with coal or coke. On heating volatilization takes place and the fumes are condensed.	Do.

TABLE VII.—Processes for the production of phosphorus and phosphoric acid by volatilization—Continued.

Patent No.	Date.	Patentee.	Reagents used.	Treatment.	Object of process.
540124	1895	Ruyinbeke, Joseph Van.	Natural phosphate, acid flux, reducing agent, air, heat.	Phosphate is mixed with an acid flux and a reducing agent, and heated in a blast furnace. Air is introduced into the upper part of the furnace to oxidize the phosphorus. The resultant P_2O_5 is carried to a scrubber.	Process for producing phosphoric acid.
689286	1901	De Chalmot, G.	Natural phosphates, silica, heat, moist lime, water.	Phosphate and silica are mixed and heated in an electric furnace. As fast as it becomes molten the mass is removed and brought into contact with a further quantity of silica. It is then dumped into water. Any phosphoric acid volatilized is brought into contact with moist lime.	Production of soluble phosphoric acid.
733316	1903	Duncan, R. K.	Phosphatic material, carbon, tar, hydrogen, heat, water, electricity.	Powdered phosphate is mixed with carbon and tar, the latter serving as a binder. The mixture is placed in an electric furnace. The resultant calcium phosphide is removed and placed in a chamber with hydrogen gas. Water is led in. The resultant phosphorus hydrides are dried and heated.	Production of phosphorus.
739433	1905	Machalske, F. J.	Phosphate rock, alkali-metal chloride (NaCl), carbon, heat, water.	Rock is crushed and mixed with NaCl and carbon. The mixture is heated. Phosphoric chloride is led off and treated with water.	Production of phosphoric chloride or acid and HCl, and carbides of calcium and sodium.
789439	1905	do.	Phosphate rock, alkali-metal chloride (NaCl), carbon, nitrogen, water, heat.	Rock is crushed and mixed with NaCl and carbon. The mixture is smelted. Phosphoric chloride is given off and may be treated with water. Nitrogen is brought into contact with the charge in the furnace.	Production of phosphoric chloride or acid, HCl, and cyanamids.
789440	1905	do.	do.	As above, with the addition that the calcium sodium cyanamides are smelted with carbon and sodium carbonate.	As above, with the production of sodium cyanide in addition.
859086	1907	Landis, G. C.	Phosphates, sand or silicate, coke, binding material, heat.	Phosphate, sand, and coke are crushed independently of each other and calcined. They are then ground, mixed, and formed into briquets with the binding material. The briquets are then fed into an electric furnace.	Process which makes excessive temperature unnecessary, prevents dust being carried over, and gives a more even action of the heat.
862092	1907	Morehead, J. T.	Phosphate rock (calcined bones, etc.), carbon, heat.	Phosphate and carbon are heated in a furnace, and the phosphorus distilling over is condensed.	Production of phosphorus and CO.
862093	1907	do.	do.	do.	A material containing calcium carbide and phosphide.
902157	1908	Maywald, F. J.	Phosphate rock, electric current, air.	Electric current is passed through phosphate rock in a furnace to which air is admitted. P_2O_5 fumes condense in a hood.	Production of P_2O_5 .
984769	1911	Levi, Giorgio.	Natural calcium phosphates, heat, SiO_2 , etc., anhydrous sodium salt, mineral colors.	Phosphate mixed with SiO_2 is heated in an electric furnace. Phosphoric anhydride escapes and is collected. Sodium salt added to the calcium silicate remaining in the furnace gives soluble sodium silicate. Mineral colors added to the silicate produce valuable colored material.	Production of phosphoric anhydride and calcium silicate, sodium silicate, and these latter colored.

1018186	1913	Haff, M. M.	Feldspar, calcium phosphate, heat	Feldspar and phosphate are heated together in a furnace. Phosphoric acid and potash are volatilized together.	Production of potassium phosphate and a slag which may be used for glass making.
1044957	1912	Washburn, F. S.	Phosphate, silica, and carbon	This invention relates to an electric furnace.	Production of phosphoric acid.
1047864	1912	do.	Natural phosphates, SiO_2 , carbon, air, heat, water.	Phosphate, SiO_2 , and carbon are heated together in an electric furnace. Air is introduced to oxidize the phosphorus driven off. P_2O_5 is treated with water.	Do.
1084856	1914	Haff, M. M.	Phosphate rock, silica, coke.	Materials are heated in an electric furnace.	Production of phosphorus and P_2O_5 .
1100839	1914	Washburn, F. S.	Phosphate rock, silica, carbon.	Materials are heated first by fuel, then by electricity.	Production of F_2O_5 .
1103910	1914	Willson and Haff.	Phosphate rock, feldspar.	Materials are fused in an electric furnace.	Production of phosphoric acid and potash.

TABLE VIII.—Processes for the production of soluble or available phosphates containing two or more fertilizer ingredients.

Patent No.	Date.	Patentee.	Reagents used.	Treatment.	Object of patent.
16111	1856	Bickell, Charles.	Feldspar, phosphate of lime, lime	Ingredients are heated together and treated with water.	Products are a double silicate of aluminum and lime, phosphate of lime, lime, all insoluble in water, and caustic potash and a little water.
26196	1859	Mapes, J. J.	Bones (100), H_2SO_4 (56), guano (30), $(\text{NH}_4)_2\text{SO}_4$ (20).	Ingredients are thoroughly mixed.	Production of phosphatic nitrogenous fertilizer.
35417	1872	Harper, Louis.	Nitrogenous organic matter, H_2SO_4 , guano.	Allowed to stand.	Restoration of guano.
39519	1863	Wilson, Geo. F.	Bone sulphate (residue remaining after treatment of bones with H_2SO_4), ammonia (obtained by distillation).	Ingredients are thoroughly mixed.	Production of "Binitro phosphate."
49891	1865	Klett, F.	Feldspar, carbonate or hydrate of lime, fluoride of calcium, phosphate of lime or iron.	Constituents are mixed and calcined at a red heat for about 5 hours.	Products are a soluble silicate of lime and aluminum and a phosphate of potassium or sodium.
61870	1867	Reimer, F.	Soil (16), KNO_3 (1), $(\text{NH}_4)_2\text{SO}_4$ (2), ground bone (1).	Constituents are mixed and cured.	Production of an economic fertilizer.
72926	1867	Grimes, W. C.	Ground bone (8 bushels), Na_2SO_4 (80 pounds), H_2SO_4 (180 gallons), urine (40 gallons), soil (10 bushels).	Ground bone, Na_2SO_4 , and H_2SO_4 are mixed. Urine and soil are added after two hours.	Production of an improved fertilizer.
77840	1868	Ramsburgh, J. S.	Bone (100), $(\text{NH}_4)_2\text{SO}_4$ (25), boiling water (3 gallons), H_2SO_4 (25 gallons), Na_2SO_4 (60 pounds), CaSO_4 (125 pounds), slaked lime (150 pounds), ashes.	Bones, $(\text{NH}_4)_2\text{SO}_4$, boiling water, and H_2SO_4 are mixed. While the mixture is hot Na_2SO_4 , CaSO_4 , slaked lime, and ashes are added.	Improvement in fertilizer.

TABLE VIII.—Processes for the production of soluble or available phosphates containing two or more fertilizer ingredients—Continued.

Patent No.	Date.	Patentee.	Reagents used.	Treatment.	Object of patent.
78730	1868	Fales, Levi S.	Raw bones, leather, blood, H_2SO_4 , sludge, NH_3 gas, peat or sea sand.	Materials are thoroughly mixed.	Improvement in manufacture of fertilizer.
88443	1869	Burkholder & Wilson.	Bone dust, oil of vitriol, Na_2SO_4 , NaNO_3 , NaCl, plaster potash, sand.	do.	Improvement in fertilizers.
100457	1870	Shepard, C. U., Jr.	Quicklime, ammoniacal water of gas works, H_2SO_4 , phosphatic material.	Quicklime is mixed with the ammoniacal water and the mixture heated. The liberated ammonia is absorbed by H_2SO_4 , but not to saturation, leaving the product in a fluid state. This fluid is then poured over phosphatic material.	Production of an ammoniated superphosphate.
100729	1870	Communs, J.	Gas liquor, blood, H_2SO_4 , steam, phosphate rock.	Mixture is evaporated to dryness.	Improvement in fertilizers.
110084	1870	Spence, Peter.	Aluminum phosphate, H_2SO_4 , NH_3 , sawdust.	Phosphate is ground and mixed with H_2SO_4 . Mixture is heated until solution is completed. NH_3 gas is run into the solution. After alum has been allowed to crystallize out, the solution is run upon sufficient sawdust to absorb it.	Production of material for the manufacture of alum and an artificial fertilizer.
124964	1872	Manwaring & Birch.	Cottonseed hulls, lime, H_2O .	Hulls are burned and the ashes taken up with water. Lime is added and the solution decanted.	KOH and $\text{Ca}_3(\text{PO}_3)_2$.
135995	1873	McDougall, J.	Acid phosphate, sawdust, NH_3 .	Ammonia vapors are absorbed by acid phosphate mixed with sawdust.	Improvement in fertilizers.
206077	1878	Boykin & Carner.	Dissolved bone plaster, NaNO_3 , Na_2SO_4 , $(\text{NH}_4)_2\text{SO}_4$, ashes, peat.	Materials are thoroughly mixed.	Improved fertilizer.
246121	1881	Graf, Leopold.	Liquid leather (obtained by boiling tanned scrap leather with KOH and water under pressure), gypsum, phosphate rock, H_2SO_4 .	Materials are mixed and heated to drive off moisture.	Do.
317010	1885	Pierce, W. S.	Aluminum and iron phosphate, $(\text{NH}_4)_2\text{SO}_4$, oil of vitriol.	Phosphate and $(\text{NH}_4)_2\text{SO}_4$ are pulverized, mixed, treated with acid, and dried.	Phosphate nitrogen fertilizer.
345625	1886	Dunne, J. J.	Phosphates, K_2SO_4 , Na_2SO_4 , coal.	Mixture is roasted to a temperature just below fusion.	Phosphate of potash.
353210	1886	Dudley, D. W.	Bone meal (1), wood ashes (1), H_2O , lime, acid, gypsum, and NaCl.	Lime is slaked in brine, mixed with gypsum and sodium chloride, and the whole mixed with bone meal and wood ashes.	Improved fertilizer.
374201	1887	Petraeus, Carl V.	Phosphate of lime, H_2SO_4 , water, K_2SO_4 , K_2CO_3 , or KOH.	Phosphate is ground and treated with H_2SO_4 . Mass is leached with water and K_2SO_4 is added to the solution. The solution is then filtered and K_2CO_3 added. On heating this solution the lime, magnesium, aluminum, and iron phosphates separate out. The remaining solution is filtered, evaporated, and cooled.	Acid phosphate of potash.
395532	1889	Williams, Wm. J.	Oil of vitriol, nitrogenous matter, water, phosphate rock.	Nitrogenous matter is acidulated, phosphate rock moistened, and the two mixed.	Improved fertilizer.
396274	1889	Endemann, H.	Tobacco stems, oil of vitriol, phosphate rock.	Tobacco stems are treated with oil of vitriol and the acid neutralized with phosphate rock.	Do.
404348	1889	do.	do.	Tobacco is treated with a mineral acid and then leached, the leachings being used to treat some basic material.	Do.
450253	1891	Reese, Jacob.	Basic slag, ammonium salt.	Materials are ground and mixed thoroughly.	Calcareous phosphate ammonium fertilizer.

450254	1891	do.	Phosphatic slag, potassium salts.....	Materials are ground and mixed.....	Production of available K_2O and P_2O_5 . Phosphatic nitrogenous pot-ash fertilizer.
450255	1891	do.	Basic slag, ammonium salt, K_2O	do.....	Phosphate potash fertilizer.
450331	1891	do.	Basic slag, KCl	Materials are ground and mixed thoroughly.	Improved nitrogen fertilizer.
484631	1892	Dumie, J. J.	Phosphatic rock, nitrogenous organic matter, oil of vitriol.	Materials are mixed and dried.	
535076	1895	Pieper, A. R. O.	Aluminum phosphate, potash lye, lime.	Materials are thoroughly mixed.	
620443	1899	Goldsmith, W. L.	Phosphate rock, soft coal, H_2SO_4 , K , and nitrogenous matter.	Materials are mixed thoroughly.	Production of citrate-soluble P_2O_5 .
709185	1902	Terne, Bruno.	Phosphate rock, oil of vitriol, NH_3 liquor.	do.....	Improved fertilizer.
731461	1903	Jarecki, A. K.	Phosphate rock, oil of vitriol, waste beet-sugar alcohol slop, addition of absorbents or driers.	do.....	Do.
897695	1908	Young, J. R.	Phosphate rock, H_2SO_4 , organic ammoniates.	do.....	Fertilizer.
911283	1909	do.	Organic ammoniates, phosphate rock, sulphuric acid, potash.	Materials are mixed.	Production of ammoniated acid phosphate.
936317	1909	Halvorsen, B. F.	Phosphate rock, HNO_3 , $Ca(NCO_3)_2$.	Phosphate rock is dissolved in HNO_3 and the excess of moisture taken up with calcined $Ca(NO_3)_2$.	Production of complete fertilizer.
988894	1911	Peacock, Samuel.	Commercial calcium cyanamid, phosphoric acid.	Cyanamid is intimately and rapidly mixed with phosphoric acid, temperature not to rise above $150^\circ C$.	Production of solid fertilizer containing P_2O_5 and N .
1001350	1911	Caro & Scheele.	H_3PO_4 , H_2SO_4 , NH_3	NH_3 gas passed into H_3PO_4 .	Mixture of calcium phosphate and calcium cyanamid.
1020293	1912	Klingbiel, Carl.	Solution of acid sodium phosphate, KCl , NH_3 , HCl .	KCl is introduced in the solution of acid sodium phosphate, and the solution is boiled. Potassium phosphate is procured by repeated boiling and crystallization. For the manufacture of $NH_4H_2PO_4$, the acid sodium phosphate solution is neutralized with NH_3 gas. The precipitate is filtered off and HCl added to the filtrate.	Stable nonhygroscopic ammoniated superphosphate.
1036969	1912	Saarbach, Ludwig.	Mineral phosphates containing carbonates, nitrogen oxides, moisture.	Phosphate is exposed to nitrogen oxides in presence of moisture.	Production of potassium or ammonium phosphate.
1040081	1912	Willson, T. L., and Haf, M. M.	Monocalcic phosphate, ammonia gas.	Ammonia is introduced into the damp or pasty mass of monocalcic phosphate.	Production of available phosphoric acid and calcium nitrate or nitrite or both.
1057876	1913	Peacock, Samuel.	Phosphate rock, gases or vapors containing nitric acid, water.	Phosphate is ground and immersed in water. Nitric acid gases are led in.	Production of dry nitrogenous phosphatic fertilizer.
1058037	1913	Collett, Emil.	Phosphate of lime, dilute HNO_3 , sulphate of ammonia, ammonia, or carbonate of ammonia.	Phosphate is dissolved in dilute HNO_3 . Sulphate of ammonia is added to precipitate lime as sulphate. Solution is separated from precipitate and neutralized with ammonium or carbonate of ammonium. It is then evaporated until crystallization takes place.	Production of material containing calcium nitrate and dicalcium phosphate.
1058145	1913	Braun, F. W.	Phosphate rock which consists principally of tricalcic phosphate and calcium carbonate, HNO_3 .	Phosphate rock is ground and mixed with HNO_3	Production of phosphate and nitrate of ammonia.
1062869	1913	Willson, T. L., and Haf, M. M.	Superphosphate, NH_3 , nitric oxide....	NH_3 is introduced into superphosphate. Acid superphosphate is added to neutralize any free NH_3 . Nitric oxide may be added.	Production of a fertilizer containing monocalcic phosphate and calcium nitrate. Nitrogen-containing phosphate.

TABLE VIII.—Processes for the production of soluble or available phosphates containing two or more fertilizer ingredients—Continued.

Patent No.	Date.	Patentee.	Reagents used.	Treatment.	Object of patent.
1099151	1914	Nicholas, F. C.	CsSO ₄ , phosphate rock, bitumen, and potash-bearing silicates.	Materials are mixed.	Production of available P ₂ O ₅ and K ₂ O.
1100638	1914	Washburn, F. S.	Phosphate rock, H ₂ SO ₄ , NH ₃ .	Phosphate rock is treated with an excess of H ₂ SO ₄ . The resulting solution is treated with NH ₃ .	Production of soluble NH ₃ and P ₂ O ₅ .
1103115	1914	do.....	Crude H ₃ PO ₄ , solution of NH ₄ H ₂ PO ₄ , and (NH ₄) ₂ HPO ₄ .	Materials are mixed.	Production of a nitrogenous and phosphatic fertilizer.
1112183	1914	Willson, T. L., and Haef, M. M.	Double superphosphate, NH ₃ gas.	Double superphosphate is treated with NH ₃ gas.	A dry nitrogenous phosphate fertilizer.
1122183	1914	do.....	Superphosphate, NH ₃ gas.	Damp pasty superphosphate is treated with dry NH ₃ gas.	Production of a nitrogenous phosphate fertilizer.

TABLE IX.—Processes for the production of soluble phosphate by electrolysis.

Patent No.	Date.	Patentee.	Reagents used.	Treatment.	Object of process.
669271	1901	Denbergh, F. P. Van...	Apatite, etc., siliceous flux, electric current, oxygen, steam or water vapor.	Apatite is crushed and together with the flux is placed in an electric furnace. Phosphorus is liberated by electrolysis in an atmosphere containing an excess of oxygen. The resultant P ₂ O ₅ is hydrated by leading steam into the furnace.	Method of producing pure phosphoric acid.
707886	1902	Wiborgh, J. G., and Palmaer, W.	Apatite or other mineral phosphate, a salt of such composition that during electrolysis an acid which forms a soluble salt with lime and a basic hydrate are formed, water, electricity.	Salt solution is the electrolyte. Phosphate is placed in the solution near the anode. Calcium phosphate is precipitated at cathode end, collected, and dried.	Production of citrate-soluble phosphate.
745523	1903	Palmaer, Wilhelm.....	Salt solution as above, mineral phosphate, CO ₂ .	During electrolysis the acid and alkaline solutions are drawn off separately. The acid solution is made to act on phosphate in a separate vessel. The alkaline solution is added until the acid reaction disappears, bicalcic phosphate being precipitated. The filtrate is mixed with the rest of the cathode solution and CO ₂ led in. This precipitates the lime and regenerates the electrolyte.	Method of producing bicalcic phosphate.
819410	1906	Clemm, Adolf.....	Mineral phosphate or bones, etc., HCl, electricity.	Phosphate is treated with HCl. The solution is separated from the residue and neutralized. It is then electrolyzed, chlorine being evolved at the anode and hydrogen at the cathode. At the cathode a precipitate of Ca ₂ H ₂ P ₂ O ₆ is formed.	Production of chlorine and citrate-soluble phosphate.

TABLE X.—Processes for the enrichment of phosphates.

Patent No.	Date.	Patentee.	Reagents used.	Treatment.	Object of process.
86574	1869	Ottolengin, A. M.	Water or air, phosphate rock.	Phosphate is ground under water and heavier particles separated by difference of specific gravity.	Method of concentrating phosphate rock.
789647	1905	Arens, Richard	Water, superphosphate, heat, calcium bisulphite solution containing phosphite (formed by treating tricalcium phosphate with sulphurous acid).	Superphosphate is leached with water, giving a solution of monobasic calcium phosphate. This solution is heated and the calcium bisulphite solution run into it. Sulphurous acid is given off and collected.	Production of dibasic calcium phosphate free from sulphurous acid.
971830	1910	Coates, L. R.	Mineral which is composed of phosphate and carbonate of lime and phosphatic fossils, heat, air.	Mineral is burned and slaked by exposure to air. The material is then screened, and the coarser particles (largely lime phosphate) are ground and added in predetermined proportion to the material that has passed the screen.	Process of unification and enrichment.
1014254	1912	Pratt, N. P.	Earthy deposits consisting of phosphate of lime and calcium sulphate, saline solution, such as sea water.	Earthy material is treated with sea water, which dissolves the calcium sulphate, leaving behind the phosphatic material in a porous condition.	Process of enrichment.
1014255	1912	do.....	Acid phosphate or other phosphate containing sulphate, suitable solvents, such as water or sea water, etc.	Phosphate is treated with a solvent which dissolves the sulphates, leaving the phosphate behind.	Do.

TABLE XI.—Processes and apparatus for the mechanical treatment of phosphate rock and soluble phosphates.

Patent No.	Date.	Patentee.	Reagents used.	Treatment.	Object of process or apparatus.
75330	1868	Wilson, G. F.	Steam or hot air, acid phosphate.	Acid phosphate is exposed in thin sheets and steam or hot air passed over it.	Production of dry acid phosphate.
75331	1868	do.....	Acid phosphate, screening.	Acid phosphate is put through screens.	Separation of coarse from fine material.
75332	1868	do.....	Bones, furnace for burning same.	Bones are placed in a special form of furnace and burned to whiteness.	Production of colorless bone ash.
75333	1868	do.....	Acid phosphate, mill for disintegrating.	The acid phosphate is disintegrated in a special form of mill in such a way as not to heat the acid phosphate.	Production of pulverulent acid phosphate.
75334	1868	do.....	Acid phosphate, grinding and screening.	The acid phosphate is granulated in a special mill and passed through screens.	Production of finely pulverized acid phosphate.
75335	1868	do.....	Acid phosphate, lead and gutta-percha pump.	The acid phosphate is conveyed by a pump made of lead and gutta-percha.	Form of noncorrosive pump for acid-phosphate liquor.
75337	1868	Wilson, G. F., and Horsford, E. M.	Acid phosphate, farinaceous material, drying platforms, heat.	The acid phosphate is mixed with farinaceous material and spread on drying platforms having a temperature of 75° F.	Production of dry acid phosphate.
86239	1869	Duval, A.	Phosphate rock, H ₂ SO ₄ , steam blast.	The phosphatic material and H ₂ SO ₄ are mixed by blowing a blast of steam against the materials as they issue from a spout.	Apparatus for mixing H ₂ SO ₄ with pulverized phosphate rock.

TABLE XI.—Processes and apparatus for the mechanical treatment of phosphatic rock and soluble phosphates—Continued.

Patent No.	Date.	Patentee.	Reagents used.	Treatment.	Object of process or apparatus.
102648	1870	Baugh, E. P.....	Guano or acid phosphate, spread on series of gratings, through which hot air is passed.	Guano or acid phosphate is spread in layers over a series of gratings, through which hot air is passed.	Production of dry phosphatic fertilizer.
105319	1870	Duval, A.....	Acid phosphate, special form of bin....	After mixing the acid and phosphate rock the product is discharged into a special form of bin.	Production of a better acid phosphate.
106147	1870	Frank & Adt.....	Acid phosphate and cylindrical drier...	Acid phosphate is put through a special form of cylinder drier.	Production of dry acid phosphate.
114693	1871	Lewis, Geo. T.....	Phosphate rock, water, grinding mill...	The phosphate rock is ground in a mill with water.....	Improvement in method of grinding phosphate.
335673	1886	Bacon, E. C.....	Phosphate rock, washing machine.....	The phosphate rock is washed in a special form of machine. (1 illustration.)	Improvement in method of washing phosphate rock.

TABLE XII.—Production of soluble or available phosphates by miscellaneous processes.

Patent No.	Date.	Patentee.	Reagents used.	Treatment.	Object of patent.
54635	1866	Wister, J.....	Bones, gypsum.....	The ingredients are thoroughly mixed and ground.....	The gypsum facilitates grinding.
67335	1867	Moore, J. H.....	Oyster or clam shells, H_2SO_4	The shells are ground and mixed with H_2SO_4 , as in the manufacture of acid phosphate.	Soluble fertilizer.
71856	1876	Ravenel, St. J.....	Phosphate rock, iron pyrites.....	The ingredients are ground and thoroughly mixed and allowed to weather.	The gradual formation of soluble phosphates.
209980	1878	Pirz, A.....	Powdered bone, $CaSO_4$	Ingredients are thoroughly mixed with water.....	Production of available P_2O_5 .
238133	1881	Lewis, Geo. T.....	Phosphate rock, coarsely broken pyrites.....	Ingredients are thoroughly mixed and exposed to weather for several months.	Do.
241868	1881	Liebig, G. A.....	Phosphate rock, carbon, heat.....	Ingredients are thoroughly mixed and submitted to high heat.....	Do.
423320	1890	Hodgkins, E. R.....	Phosphate rock, CaO , water.....	The phosphate rock is finely ground and piled in alternate layers with CaO . The whole is sprinkled with water.	Do.
43749	1891	Van Ruymbeki, J.....	Aluminum phosphate, "stick," $CaCO_3$	Phosphate rock and $CaCO_3$ are thoroughly mixed with "stick" liquor.	Production of dry product containing available P_2O_5 .
493889	1893	Gordale, S. L.....	Hydrated phosphates of iron and aluminum.	Mixture is heated to 275° to 325° C. and allowed to cool.....	Production of available P_2O_5 .
517661	1894	Powter, N. B.....	Aluminum phosphate and slaughter-house refuse.	Ingredients are thoroughly ground and mixed.....	Production of fertilizer.
517662	1894	do.....	do.....	do.....	Process of making fertilizer described in Patent No. 5171.

714330	1902	Reese, Jacob.....	Phosphate rock, oxides of iron and manganese, heat.	Ingredients are mixed and heated in presence of oxidizing flame.	Production of citric-soluble phosphate.
789440	1905	Machalske, F. J.....	Phosphate rock, NaCl, C, N, Na ₂ CO ₃ , heat.	A mixture of phosphate rock and NaCl is fused in an atmosphere of N. FCl ₃ is led off and the residue fused with Na ₂ CO ₃ .	Production of PCl ₃ and Na ₂ C ₂ N ₂ .
792314	1905	Chisolm, Wm. B.....	Phosphate rock, sulphur, CaO, water....	A mixture of sulphur, lime, and water is first heated until the mass is homogeneous. This is mixed with phosphate rock and the whole dried and ground.	Production of available P ₂ O ₅ .
824280	1906	do.....	Phosphate rock, sulphur, N or K bearing materials.	Phosphate rock and sulphur are intimately mixed and ground.	Production of fertilizer containing available P ₂ O ₅ .
824281	1906	do.....	Phosphate rock, sulphur, grinding.....	Nitrogen or potash bearing materials are added. Phosphate rock and sulphur are first roughly crushed and then passed into a mill, where they are finely ground.	Process of preparing mixture for fertilizer described in Patent No. 824280.
947795	1910	Coates, L. R.....	Sterilized culture mixture, breaking-down-rock containing microorganisms, some food for bacteria, phosphate rock.	Breaking-down rock is added to culture mixture, giving culture which causes rock decay; sterilized ground bone and sterilized phosphate rock are added.	Production of available P ₂ O ₅ and K ₂ O from insoluble minerals.
1002143	1911	Frerichs, F. W.....	Phosphate rock (NH ₄) ₂ SO ₄ , heat, water.	Phosphate rock and (NH ₄) ₂ SO ₄ are mixed and roasted till a temperature of 500° C. is attained. NH ₃ and H ₂ O escape and a mixture of calcium metaphosphate and CaSO ₄ remains in retort. This is treated with water.	Production of calcium metaphosphate and ammonia.
1002248	1911	Ellis, Carleton.....	Phosphate rock or basic slag, humus or peat, borax waste, lime, saccharine material, nitrogen-assimilating bacteria cultures, heat.	The humus or peat is first sterilized by heat or borax waste. It is then mixed with phosphate rock; lime and material containing nitrifying bacteria are added. Saccharine material may be added to aid growth of bacteria.	Production of available P ₂ O ₅ and process of producing same.
1032783	1912	Newberry, S. B., and Barrett, H. M.	Phosphate rock, carbon, heat, air.....	Phosphate rock and carbon are ground and mixed. The mixture is then strongly heated, first in reducing atmosphere and then in oxidizing flames. Product is ground.	Production of citrate-soluble P ₂ O ₅ .

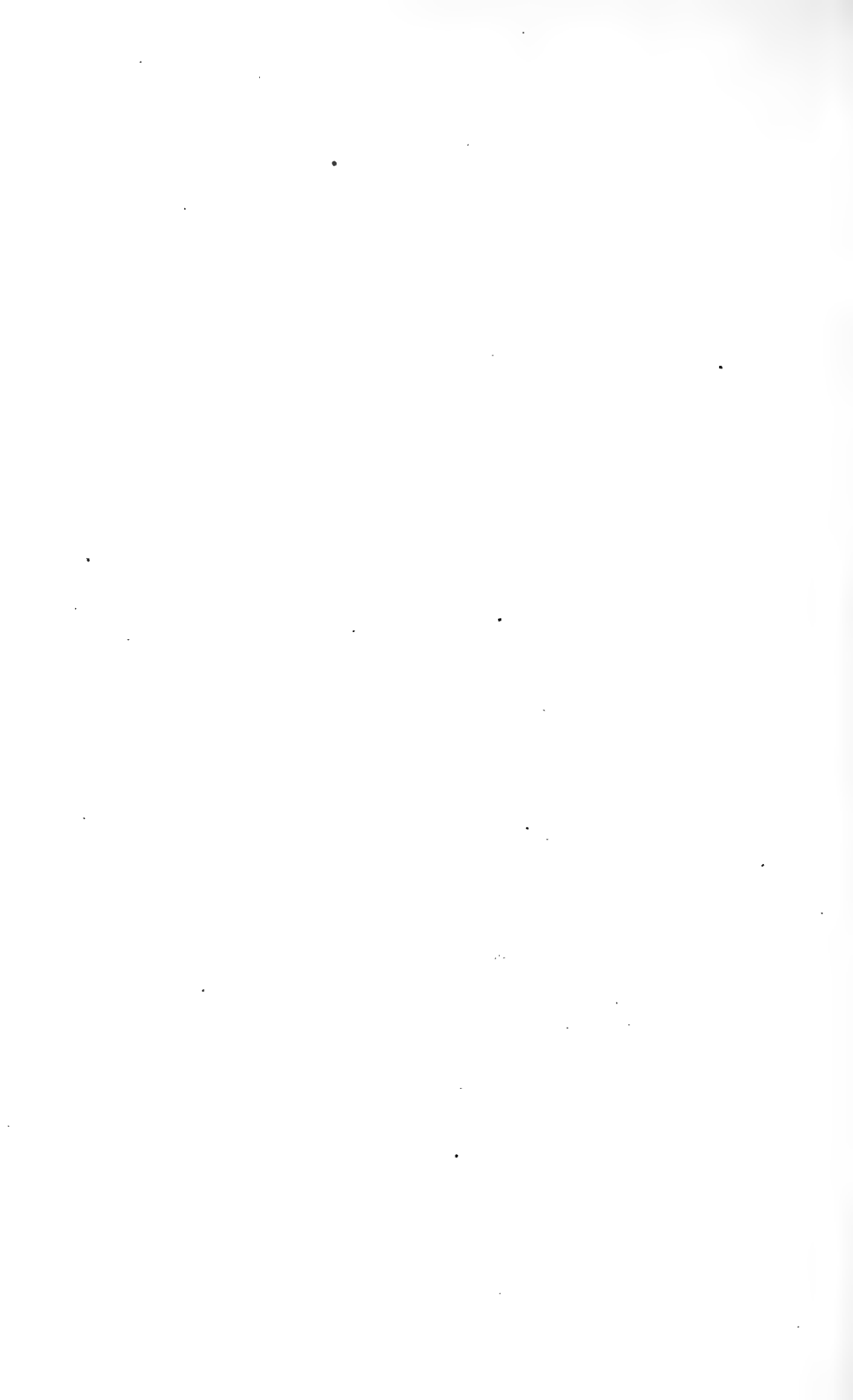
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UNITED STATES DEPARTMENT OF AGRICULTURE



BULLETIN No. 313

Contribution from the Bureau of Animal Industry
A. D. MELVIN, Chief.



Washington, D. C.



November 13, 1915

FEATURES OF THE SHEEP INDUSTRIES OF UNITED STATES, NEW ZEALAND, AND AUSTRALIA COMPARED.

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INTRODUCTION.

In July, 1914, funds became available to the Animal Husbandry Division to be used "for the importation of Corriedale and other promising breeds of sheep for breeding purposes." In August, 1914, the writer reached New Zealand to study the breeds of sheep in that country, and later spent six weeks in Australia visiting sheep stations, shearing sheds, wool markets, and officials of agricultural departments conducting experimental and educational work relating to sheep raising. As a result of these observations and study, it was decided to use the funds available for the purchase of a foundation flock of Corriedales, and 53 ewes and 10 rams of that breed reached the Federal quarantine station at San Francisco on December 31, 1914. The adaptability of these sheep and their offspring to conditions in the Rocky Mountain States will be tested and reported in the future. The history and characteristics of Corriedale sheep are discussed later on in this bulletin.

American sheep raisers have not remained wholly unacquainted with the ideas and practices of Australian flock masters. During the past year lectures delivered in western States have done much to familiarize sheep raisers with the very efficient Australasian system of getting wool from the sheep to the mill. For some years persons connected with the wool trade have made it clear that in many phases of sheep raising, especially that of preparing wool for market, American methods compare very poorly with those followed in Australasia.

With conditions as they are at present, when sheep raising contains so much of promise and also of uncertainty, it is well to have at hand as much information as possible regarding the fundamental principles that have so firmly established the sheep industry in Australasia and made these far-off countries so prominent for both quantity and quality in the world's wool trade. Because of these considerations, the impressions gained from a comparatively rapid view of sheep and wool matters in New Zealand and Australia by one having the American viewpoint have been prepared for publication.

GENERAL CONDITIONS IN NEW ZEALAND'S SHEEP HUSBANDRY.

Sheep raising in New Zealand is conducted on lines midway between those followed in our farming States and in the range States. In comparison with American farm flocks, those of the smaller holdings in New Zealand have an advantage in that they rarely number less than 400 head and are a very important, if not the chief, source of revenue from the holdings.

The total area of occupied land in New Zealand is under 45,000,000 acres. Of this, 5,000,000 acres have been plowed and sown to artificial grasses for grazing, while over 9,000,000 acres have been surface-sown to artificial grasses without plowing. The first-mentioned lands support from 1 to 8 sheep per acre for the year, while the latter average from one-half to 2 sheep per acre. Grass is the principal crop. With a growing season of 10 months and a well-distributed rainfall, it is found profitable to keep in grass for stock alone lands valued as high as \$150 per acre. Nearly one-half the occupied land is in holdings of over 5,000 acres, mainly used for sheep, there being 90 holdings of over 50,000 acres each against 18,694 holdings of from 50 to 200 acres.

The number of sheep kept has advanced from about 19,000,000 in 1896 to 24,595,405 in April, 1914. This enumeration for April corresponds to November in the United States, coming after a large proportion of lambs have been marketed, and corresponding quite closely to the numbers of the shearing season to follow. Wethers, rams, and ewes under breeding age comprise about one-half the sheep

population. The number of sheep slaughtered for food purposes during the 12 months ended March 31, 1914, was 4,019,831, and of lambs 4,338,180. The 1913 exports numbered 3,538,488 lamb carcasses and 2,201,365 carcasses of mutton.

New Zealand's flocks number 21,500, and the average size of flock has increased from 1,081 in 1896 to 1,124 in 1913. About one-half the sheep are in flocks numbering less than 2,500 head, while seven-eighths of them are owned in flocks numbering over 500 head each.

A contrast of these figures with others for the leading farm-sheep State and the leading range-sheep State in this country is of interest.

Sheep in New Zealand, Ohio, and Wyoming.

State.	Total land area.	Sheep in State. ¹	Holdings over 100 acres. ²	Holdings having sheep.	Average size of flock.
	<i>Acres.</i>	<i>Number.</i>	<i>Number.</i>	<i>Number.</i>	<i>Number.</i>
New Zealand.....	66,292,232	24,595,405	25,702	21,527	1,124
Ohio.....	26,073,600	3,263,000	94,754	71,556	55
Wyoming.....	62,459,160	4,472,000	9,584	1,643	2,938

¹ Jan. 1, 1914.

² In 1910.

It is partly because of necessity that New Zealand lands are so largely devoted to sheep raising. A good quality of mutton and wool can be produced without the feeding of grain, the production of which is not favored either by the soil or by labor conditions. On the other hand, the place occupied by sheep is evidence of the profits obtainable when valuable lands are devoted to well-managed flocks of sufficient size to insure for them the lively interest and careful tending essential to their well-being and which in our farming States is the exception rather than the rule.

While it is true that the values of other commodities do not call for other uses of land as in our farming States, this fact is offset by the lower prices paid for mutton and lamb in New Zealand. The advantage enjoyed there in the price of wool is quite largely due to the exercise of superior skill in preparing the clips for the market. It is true also that New Zealand flockmasters have no predatory wild animals to contend with. The problem of the domestic dog is not absent, however, but the dog is held in check, because the general and predominating interest in sheep gives support to well-enforced laws. Our farming States have experienced a decline in sheep raising on account of unequal competition from cheap western lands. The force of that competition no longer exists, and the agriculture of the Middle and Eastern States will not again exhibit its most profitable status until the flocks of sheep therein are larger and much more numerous than at present. The main difficulty in the way is

lack of appreciation of the results obtainable from carefully tended flocks.

GENERAL CONDITIONS OF SHEEP HUSBANDRY IN AUSTRALIA.

Even a superficial study of the peculiar phases of the sheep industry in the country where it has its greatest magnitude must be of great interest and may be very profitable. While conditions and customs of sheep raising vary greatly in Australia, the variations are less marked than in the United States. The sheep industry of Australia is still in the main what an American would call a "range proposition." Crossbreeding and mutton production are of less concern even than in our Rocky Mountain and other western sheep-raising States.

New South Wales, Victoria, and Queensland possessed 85 per cent of the 83,263,686 sheep in Australia in 1912. Queensland is the largest and least developed of the three States mentioned. Eighty per cent of its land is occupied, 74 per cent being held under Government lease or license. On the 343,000,000 acres occupied in Queensland there are 3,119 flocks which average 6,500 sheep. Data regarding size of holdings and size of flocks are available only for New South Wales and Victoria, consequently figures for only these two States, which possess 60 per cent of the Commonwealth's sheep, are shown in the following table, and data for the western United States are included for comparison:

Sheep in New South Wales, Victoria, and the western part of the United States.

Section.	Total area.	Total area owned. ¹	Per cent of area having 15 inches or less rainfall.	Area under lease or license.	Total acres in holdings over 100 acres.
	<i>Acres.</i>	<i>Acres.</i>	<i>Per cent.</i>	<i>Acres.</i>	<i>Acres.</i>
New South Wales.....	198,054,420	57,818,023	39.4	124,590,163	181,195,753
Victoria.....	56,245,760	31,055,920	37.0	14,443,191	44,502,618
Rocky Mountain States ²	398,599,680	47,016,786	72.0	.....	45,155,275
Southwestern States ³	319,175,040	124,951,701	15.0	.....	113,281,343
Pacific States ⁴	203,580,800	51,328,789	37.0	.....	48,027,762

Section.	Total sheep.	Sheep per acre on holdings over 100 acres.	Number of flocks.	Average size of flock.	Sheep in flocks over 1,000.
	<i>Number.</i>	<i>Number.</i>	<i>Number.</i>	<i>Number.</i>	<i>Per cent.</i>
New South Wales.....	38,855,861	0.21	25,549	1,520	84.5
Victoria.....	11,892,224	.25	24,838	480	59.7
Rocky Mountain States ²	18,196,574	.308	11,323	1,607	86.8
Southwestern States ³	6,382,426	.056	11,881	537	80.6
Pacific States ⁴	5,592,167	.116	12,368	452	89.7

¹ Reported as in farms for United States.

² Idaho, Montana, Nevada, Utah, Wyoming, Colorado.

³ Texas, Arizona, New Mexico.

⁴ California, Oregon, Washington.

Much of the land in Australia now used as sheep runs is destined to be used for farming. "Closer settlement" is actively assisted by all the State governments. Taking the Commonwealth of Australia as a whole, one-third of its land area lies in regions of less than 10 inches of annual rainfall. In these drier sections salt bush furnishes a large part of the sheep feed and is considered most satisfactory for dry sheep. Outside these sections the country enjoys peculiar advantages favoring sheep raising, particularly in comparison with those areas of the United States which now and for an indefinitely long period can be used most profitably for the grazing of sheep.

In considering sheep raising in Australia, it should always be borne prominently in mind that the flocks, or "mobs," are not kept collected and under the care of herders while pasturing. The lands are fenced into "paddocks" of from 500 to 10,000 acres in size, and the sheep run safely at liberty in these. The lessening of labor by this plan is no more important than the greater thrift of the sheep as compared with those in charge of even the best herders.

The amount of pasturage procured from each acre is much greater under the paddock plan. The fact that the sheep are very widely spread out at all times and never driven over dusty trails to and from dusty bedding grounds gives cleaner and lighter-shrinking wool from the Australian flocks, aside from the advantage of some regions in having soils that are not inclined to blow. Fencing the sheep runs and dividing them into paddocks of suitable size requires labor and expense, which, however, are much more than counterbalanced by subsequent saving in the labor of handling the flocks and in the extra thrift of the sheep. In many cases sheep are mustered or rounded up but once in the year, at shearing time. Having their full liberty in paddocks from 500 to 10,000 acres in size, they are under practically natural conditions. The absence of wild animals from the paddocks and the climate together avoid the necessity for attention at lambing time, except in the case of valuable stud ewes. On the other hand, difficulties with hired labor are greater in Australia and wages little if any lower than in the United States. The blow-fly is a serious pest in much of the country and necessitates frequent inspections, as well as crutching and dipping, which involve expense.

Droughts, which occur with some regularity, are exceedingly serious. The number of sheep may be reduced by nearly one-half over large areas once in 10 years, entailing desolation and serious loss, especially to the smaller owners who can not move their stock and to owners who have stocked their lands to their full capacity in normal seasons.

Vegetation recovers with exceeding rapidity at the breaking of a drought, and with the climate aiding the Australian Merino sheep's habit of breeding at practically any time of the year, the flocks are

quickly reestablished. Serious and widespread as are the Australian droughts, the handicap they impose upon the sheep business is not so great as appears at first sight. Only in such times is it necessary to feed the flocks in that country. With extra feed available, less is needed to maintain an animal through a drought period than through a period of cold and storm such as is experienced with greater frequency by American flocks.

TENURE OF PASTORAL LANDS.

The high rank of the Australian and New Zealand sheep raisers is due in part to the newness of their countries. Many areas now devoted to sheep raising will ultimately be used for crop production. The fact that settlement is in its earlier stages affords greater scope and opportunity for pastoral pursuits. In the United States the sheep raiser has repeatedly been forced by the farmer to retreat to the drier, rougher, and more remote sections. It is a question whether the value of the total output of some sections has not been reduced as a result of the abandonment of grazing consequent upon the taking up of a few claims for farming.

In large part, however, the efficiency of the Australasian pastoralist is due to the system under which he secures and holds his grazing lands. No Australasian sheep owner uses public domain without charge; neither is he in any danger of having the lands he has leased grazed by stock other than his own. In some "back" sections the cost of his lease may be practically nominal, but it gives him full use of the land and renders him liable to higher rates at such time as settlement has approached him and the lease value of the land has advanced. The conditions governing leasing, like those concerning the acquiring of freehold, vary considerably with the different States.

LAND LEASING.

The leasing policy appears to have been found satisfactory by the governments of the various States and is generally approved by the lessees. The acreage of land under lease in the Australian Commonwealth increased from 1901 to 1912 by 19 per cent, or over 137,000,000 acres, and in the latter year constituted 45 per cent of the Commonwealth area. New South Wales had 62 per cent of its area under lease, Victoria 25 per cent, and Queensland 74 per cent. The last-named State in 1912 granted 348 leases for grazing homesteads, averaging 11,000 acres each, and 223 leases for grazing farms, averaging 8,228 acres.

In leasing provision is made for later resumption of lands by the Crown for division for smaller pastoralists or farmers. In such cases the original lessor retains his own central homestead and receives compensation for improvements upon lands resumed by the Crown.

The Australian pastoralist who pays for the use of his lands according to a long-time contract is at a great advantage over the American pastoralist who enters into unlimited competition for wholly temporary and unlegalized use of public lands. The Australian enjoys the control of the land he uses, and the length of his tenure encourages and justifies him in making investments necessary for the proper utilization of such land. He knows he is safe in making a generous expenditure of his time and capital in breeding his flocks to the highest point of efficiency, because after the result is attained he still has time under his lease to reap the benefits of his accomplishment. This is true, also, in regard to construction of fences, shearing sheds, and accommodations for labor. He builds for himself a reputation for producing a high quality of wool and for preparing it for market in an attractive and reliable manner, and is assured of remaining upon the same land long enough to reap the benefits of the reputation established for his output.

Too commonly, and not without justification, the American wool producer argues that an investment in improved stock or in the appliances and intelligence required to secure a good reputation for his product can not safely be undertaken because of the uncertainty of his continuing in business long enough to reap the benefits. It is well known that under this lack of system the public range has been so overcrowded as to diminish most seriously the amount of feed produced, and consequently its value to the Nation. While it is true that such use as is made of the public domain is made without charge to sheep owners, it is quite plain that a more permanent and better-managed industry would result from a settled policy of leasing or apportioning for fixed periods, under a permit system, the remaining public lands suitable chiefly for grazing, and in blocks of the size necessary to permit the most economical management.

Users of the American public domain are themselves becoming more agreed as to the desirability of a definite policy for control and improvement of the public grazing lands, even at added cost to themselves. Such a policy is urgently needed to secure for the country the maximum production from its 290,000,000 acres of unappropriated and unreserved public lands lying mainly in the Western States.

The State of New South Wales, Australia, is divided into 67 pastoral districts. For each district there is a pastures protection board, consisting of eight members, elected by the landowners and stock owners within the district. Acting through these the stock branch of the State Department of Agriculture enforces the provisions of the pastures protection act. The members of the local boards are themselves stock owners and enforce the laws in respect to diseases, quarantine and movement of sheep, fencing against rabbits, and payment of bounties for destruction of noxious animals.

The expenditures of the boards are paid from funds derived from rates levied upon the land and stock within the district.

FLOCK MANAGEMENT.

In general the policies of Australian flockmasters are more continuous and more completely worked out than in the case of the general run of American flocks. Remoteness from markets and limited crop production have occasioned less attention to mutton and more to wool. The method of selling the wool and the system of land tenure have facilitated progress in breeding and in management. The majority of sheep raisers appreciate the value of good blood and careful matings and steadily adhere to a plan of breeding to produce sheep having the peculiar characters necessary to adapt them to the particular sections.

Whether it is due to a peculiar attitude toward his business, the insistence of interested capital, or the favorableness of the climate, the general custom of having the station manager reside permanently upon the property he superintends is in marked contrast to the custom of American sheep ranchmen, and in general the management is in most respects more efficient.

It has already been explained that Australasian flocks running at liberty in large fenced paddocks require and receive no such continuous shepherding as is necessary in American flocks. Although the flocks of considerable size are all of Merino blood, the propensity to herd closely is not desired. The sheep in a paddock form into groups, each of which keeps to its own general area. The sheep are rounded up or driven only when required for shearing, classing, etc. Practically no supplementary feed or cultivated grasses are used. Part of the labor saved in herding is offset by the employment of boundary riders to attend fences and wells, and a great many men are needed to keep rabbits in check. The number of hands steadily employed upon a sheep station in Australia is less than for an American ranch carrying a similar number of sheep, while the number of extra men employed at shearing time is greater.

CLASSING SHEEP.

Ewes are ordinarily classed for breeding just previous to being shorn. This time affords the best opportunity to judge of the fleece and divide the ewes into uniform lots, each of which is later mated with rams chosen to improve defects of fleece or form. Classing at this time also gives fleeces of fairly uniform character, which facilitates the work of the wool classer who is always employed at shearing time. In some cases a lot of young ewes once classed up are kept in the same groups as long as they are bred from. In other cases classing of all ewes is done each year.

This division of the ewes into uniform lots is deemed to be of greatest importance. On one station visited, where only wethers are kept, it is the custom to go over purchased stock before shearing and make an examination of each fleece. Once assorted in this way a flock may run for several seasons with only such re-sorting as is made necessary by mixing or the presence of strays. After shearing, the ewes need only such attention as is given by the boundary riders until breeding time, when mustering is necessary only to remove the rams at the close of the season.

LAMBING RETURNS.

The lambing returns do not differ widely from western American figures. Three per cent is the common proportion of rams used. Lamb crops vary around 80 per cent, less in young ewes and more in stud ewes. Where the blood of British or mutton breeds has been introduced larger lamb crops result.

Fall-dropped lambs are separated from their dams at shearing time and, though only 3 to 5 months old, are also shorn. Shearing at this age allows better growth of the lamb and gives their yearling fleeces greater uniformity in length and quality.

BUILDINGS.

Aside from the shearing sheds, no buildings for sheep are seen except occasional sheds in near-by paddocks to keep the sheep dry as they come up for shearing. No feed of consequence is harvested or stored. In drought times purchased feed may be fed, but the commoner plan is to ship the sheep to points where grazing can be leased.

BREEDS AND TYPES OF SHEEP IN AUSTRALIA.

Over 70 per cent of the sheep in Australia to-day are of Merino breeding. Of the crossbreds that make up a large part of the balance, most are from Merino ewes. Australia's sheep industry began with sheep of Spanish Merino blood imported from the Cape of Good Hope and from England, late in the eighteenth century. Considerable numbers of Saxony Merinos were taken to Tasmania and that State for some time produced many of the rams most highly esteemed on the mainland. The Australian Merino has therefore sprung from the same original stock as the American Merino. In the palmy days of fine-wool sheep breeding in Vermont many sheep were exported from that State to Australia. American Merinos are seldom spoken of by that name in Australia, but one frequently hears "Vermonts" referred to.

For an American, the point of greatest interest and value in Australian sheep husbandry is the type of sheep that has been evolved for the profitable production of wool. There is nothing in

material or methods available in Australia that can not be used in the United States. It has been stated that Australians are familiar with what they call the Vermont sheep and that the use of that blood has mainly been discontinued. In fact the terms used nowadays in Australia in referring to the "Vermont" sheep are far from complimentary, and would seem to overlook the improvement in density and quality effected by American Merinos. Objection is made to the excessive wrinkles on the body, to excess of oil in the wool, to shortness, and too great fineness of the wool. These objectionable features are considered to be indicative of and associated with a lack of constitutional vigor.

DIVERGENCE OF AUSTRALIAN AND AMERICAN MERINO STANDARDS.

It would be unwise and un-American to fail to give due weight to the Australian criticism of a type of sheep which is still largely kept in this country, especially since until recent years the standards of the two countries were quite similar. The plan of selling wool, whereby the price received by the grower is set by the manufacturer's buyer, enables the Australian to make a more accurate estimate of profit from various types of wool. The Australian argues that the extra price received for the very fine wools does not offset the value of the greater quantity of "robust" wool secured per acre of land used with the type of sheep now favored. The clearly defined areas of leased land, with no transfer from winter to summer range, also give an added advantage in determining production costs.

Corresponding to the A, B, and C types of American Merinos now recognized apart from the Rambouillet, Australia has the fine, medium, and strong types. None of these can be said to resemble the Rambouillet closely. The "strong" or "robust" wooled type produces a fleece of considerably greater clean weight than is obtained from the finer, tighter-wooled type. The greater bulk and length of the robust fleeces, together with the lessened amount of oil, give a much greater weight of clean wool per sheep than is yielded by the finer-wooled sheep. While the coarser wool may at times be worth less per clean pound than fine wool, it has for some years suffered no discount, and it is found easier to maintain in that uniformity of crimp and brightness that has much to do with fixing values. A further claim for the production of this robust wool is that the sheep which produce it are larger and stronger in constitution.

AUSTRALIAN OPINIONS AS TO ROBUST WOOL.

The following extracts from matter published in Australia in this connection shows the development of opinion in that country. In 1899 Mr. Jeffrey, Government wool expert in South Australia, wrote:

FINE WOOL VERSUS ROBUST.—Because of the many different types in the Merino class, it is most important to know what particular type is most adapted

for the locality on which they are depastured. But on account of the varying conditions met with throughout Australia, such as difference in country, climate, etc., as was stated in an earlier portion of this chapter, no definite type can be suggested for each locality; still, taking for granted that the object of the wool grower is to keep sheep which will yield most money per head, and not sheep the wool of which simply realizes fancy prices per pound, some authorities maintain that, in most localities at any rate, financial advantage would be gained by the keeping of a more robust type of sheep than is generally found to-day. Whether such authorities be correct or not, it is a fact that the trend of wool is fast developing in the direction of a little more robustness or strength.

In proof of this some of the best known fine-wool growers in Australia, who have for years past obtained amongst the highest prices for their wool, are purchasing rams from well-known robust-wooled flocks, in which, for a considerable time, great attention has been paid to this type of wool, with the most satisfactory results.

It would be folly to suggest that the robust-wooled sheep, such as are found in South Australia, would be entirely suitable for every locality in Australia; still, a strain of stronger blood in most of the fine-wooled sheep would perhaps be of advantage.

In the drier or more arid parts, such as the Barrier district of New South Wales, the north of South Australia, and other similar localities, experience has proved that it is impossible to keep fine-wooled sheep with anything like the most satisfactory results. This type of sheep (if greasy) is much inclined to sweat, and the skin is too thin to withstand the severe punishment which is met with in such localities.

The hair follicles or bulbs on the surface of the skin are very susceptible to the withering effects of the climatic conditions met with there, and the somewhat tender or delicate fiber can not endure the hardships which are so common under such conditions.

All this will have more weight when it is remembered that wool has a tendency to become finer, and in the hotter and drier parts, should it be fine to start with, it generally goes "off" and becomes loose and open (particularly on the back), with the result that the dust and sand, which are so prevalent there, find their way right on to the very skin of the sheep, causing more or less injury to the fiber.

Further, on account of the excessive openness, the heat of the sun much more easily operates upon the wool, extracting from it the yolk, which is the very life of it, thereby leaving it tender, mushy, and lifeless.

On the other hand the robust or stronger-wooled sheep is eminently fitted to endure the hardships met with under such conditions, the skin being thicker and less inclined to sweat, the hair follicles or bulbs less susceptible to climatic effects, and the fiber stronger and hardier.

Again, the wool being strong to start with, will not so readily "go off" and become loose and open as the fine and delicate wool would, thus making it more able to withstand the ravages of the sand, dust, and sun.

At one time it was objected that strong-wooled sheep of the robust type, on being taken to the drier parts, produced wool which became coarser, in fact, which developed into hair, and it has to be admitted that there was much truth in the objection; but the nonsuccess lay in the fact that the wrong type of robust-wooled sheep was taken up to these parts, and not that the robust sheep in itself was at fault.

The failures were, generally speaking, caused by the use of rams of nondescript type without any character in their wool, whereas, what is required and

what has proved eminently successful, is the use of well-bred rams with plenty of character in the wool, which is denoted by the crimps or curls being well and evenly defined.

The argument that the extra price obtained for the finer wool justifies the keeping of fine-wooled sheep in these arid parts does not hold good, because in the first place the fine wool, being generally more wasteful, will yield to the manufacturer less than the average percentage of "top" and more "noil," and as the noil is worth much less than top, it will be clear that the price obtained per pound in the grease must on that account be lessened.

Even granting that the fine wool be healthy, and with a good "tip," the small difference in value between it and the stronger wool is far more than made up by the extra weight from the stronger-wooled sheep. In fact, it can be said truthfully that the robust wool referred to fills the hand, fills the bale, and eventually fills the pocket of the careful grower.

Believing that the introduction of the strong-wooled strain already spoken of will become more common, it will be well to anticipate the alarm of some of the extra-fine-wool growers who will maintain that by the introduction of a somewhat stronger strain the repute of the far-famed Australian high-class wool will be damaged, but it should be stated that by such introduction there is no reason why the character of the wool should be in any way altered, because the fresh strain introduced should be only of the very purest. Besides, it is only reasonable to suppose that many of the fine-wooled-sheep farmers, on account of the eminently suitable conditions under which their wool is grown, will still adhere to their type of sheep, so that any fear as to this class of wool becoming extinct may be allayed. In fact, there is little doubt that the demand for such qualities of wool will always be met, for it has to be admitted that such demands are not nearly so common to-day as they were in times past, the reason being, no doubt, largely on account of the much improved machinery used in the manufacture of wool.

The following, written by "Camden," appeared in the *Pastoral Review* of August, 1914, page 770:

So much water has run into the sea since the days when the Australian sheepfold was divided into opposing forces on the subject of development that one can now refer to folds and wrinkles without stirring up even the mildest form of hornet's nest. And yet it is not so long ago, after all, that the subject was referred to with bated breath. Well within the last decade, those of us who moved about amongst stud flocks frequently heard ourselves remarking upon the "wonderful development" of sheep under inspection, and curiously enough that wonder was not diminished when we had to dig in among the folds and corrugations in search of indications of the true character of the wool.

In this article I have inserted two photographs which illustrate the change that has come over the scene. The photo of the wrinkly ewe was taken within the last 10 years. She was champion medium-wool housed ewe at the Sydney show, and was immensely admired by a great many sheepmen at the time. Now, I would like to ask, Does one sheepman exist at the present day who does not think that the type of sheep represented by the illustration is not over the odds? We can all admire the sheep as a triumph of breeding, but as a commercial proposition at the present day what can be said in favor of a ewe like this? In the first place, what chance would there be of growing a fleece uniform in quality and length on a skin so corrugated? In the second place, it has been found that sheep of this type burden themselves with excessive grease, which in its turn accumulates dirt, so that the animal, already handicapped, is forced to bear the additional weight of rubbish that has no commercial value. And, lastly, but by

no means least, the type represented by the photo could not be better designed as an attraction for the blowfly. The thick fleece, excessive grease, tight wrinkles combine to set up conditions extremely favorable to the operations of the maggot fly.

In order to show the contrast between a stud Merino ewe of 10 years ago and the present day, another photo is inserted in this article, and it is safe to say that as a commercial sheep it represents almost the ideal type of Merino. With sheep of this type there is a chance of maintaining, to say nothing of building up, constitution. There is also a chance of maintaining evenness of length and quality throughout the fleece. This type of sheep also carries a characteristic that adds to its value, viz, a freedom from excessive grease. The wool handles free and soft, and is less liable to accumulate dirt and rubbish. Viewing these two photos side by side throws a good deal of light upon Merino history of the last decade or so, and they tell the following story:

In the first place the early breeders started off scratch and type was fairly uniform. As the years went on and the breeders brought the results of their experience into operation they gradually divided themselves into two main bodies. One side remained fixed in its idea as to what constituted a commercial sheep and a sheep most suited to Australian conditions. It kept to the plain body and the light fleece. The other side steadily set out to improve the weight of fleece. People of this opinion also noted that the tendency of sheep run in the hot interior was to get light and fuzzy on the back, and they considered that more yolk or grease was necessary to counteract this. And so the two factions pursued their different ways, one side sticking to a plain, ordinary-looking sheep, while the other quickly developed a type that could not fail to excite the wonder and admiration even of those opposed to the type. Breeders of this school endeavored to put on weight of fleece, and they found that as they mated for density more folds and wrinkles were produced. It soon came to pass that they found their best stud sheep among the wrinkly ones, and the doctrine spread that weight of fleece could not be maintained, let alone increased, unless there was plenty of "development" in the stud sheep. The leading Merino shows helped to force this doctrine upon the public, and for years the principal prize winners at shows were the most wrinkly sheep.

The lesson that Australian sheepmen were learning was expedited and eventually brought to its crisis by the enterprise of several wealthy and prominent breeders, who imported the densely clad, heavy-yolked Vermont sheep. These sheep set an ideal before sheepmen who favored that type, and the zenith was soon reached. * * *

While all this progress was taking place those breeders who remained firm in their belief in the plain-bodied, free-wooled type of Merino increased their efforts to improve their sheep without departing from those lines. They predicted that a reaction would take place, and they made themselves ready to meet it. The pendulum swung back to the plain-bodied sheep, and in doing so gave such an impetus to the owners of the big, plain-bodied, grass-fed stud flocks that they improved their sheep out of all recognition. Take any of the big stud flocks in Riverina, western New South Wales, and South Australia to-day and it will be seen that the sheep are superior in every way to their best standard of 10 or 15 years ago. The frames have been built up into better symmetry and heavier fleeces have been put on without loading the sheep with additional grease or body wrinkles. The achievement of results in breeding is necessarily a slow process, but Merino history has been made so fast in Australia within the last 10 years that the ideal type of sheep has become universally acknowledged. Where 10 years ago there was discord on this subject there is now harmony, and all practically agree as to the ideal type.

It should also be mentioned that the most highly esteemed Australian rams have an "open" face in contrast to the heavily woolled face demanded by American breeders. Covering of wool on the legs is desired, but only as a minor point.

The type of sheep so popular for the drier, warmer sections with scattered feed might not prove to be fully adapted for our western States, but there is food for much thought in the Australian's severe criticism of wrinkles, fine wool, heavy oil, and thin skin. Aside from the influence upon wool growth of extreme warmth and dryness, it must also be granted that our winters prevent us from producing the length of wool and the uniformity in quality, appearance, and character possible under conditions occasioning no such checks. When running at liberty in paddocks, even on a light, dry soil, there is not the same amount of dirt in the fleece that is unavoidable under a system of continuous herding and several nights' use of, and daily driving to and from, a single bedding ground.

The demand of the American buyer in Australia for a light-shrinking wool has no doubt lent an added stimulus to progress in that country, but such progress even if altogether so promoted is none the less worthy of the attention of our sheep breeders and woolgrowers.

MUTTON POINTS OF AUSTRALIAN MERINOS.

Although frequent mention is made of the value of the carcass in discussions of the recently evolved Australian Merino, that sheep does not seem to be the superior of the American Merino in either size or points of mutton conformation. In both regards it is inferior to the Rambouillet as bred in the United States. The Rambouillet is little known or understood in Australia. There appears to have been some use made of an earlier type of the breed by the Peppyns, whose sheep in other hands have contributed largely to the advance of recent years.

SALES OF STUD RAMS.

Many very large and very valuable stud flocks are maintained. A few of these contain upward of 60,000 ewes, and one flock has sold as high as \$260,000 worth of rams in a single season, at an average price of \$30. At the 1914 annual ram sale held in Sydney, 268 Merino rams were sold, at an average price of \$437, while over 2,500 other rams brought an average of \$38. With a demand for flock rams in lots of 100 and more, at \$20 per head, the stud sheep business is attractive to competent breeders and justifies paying two or three thousand dollars for a sire, as is commonly done. Over \$7,000 has been given for single rams on several occasions. Such prices are not known in America, although breeders are not wanting whose sheep are capable of effecting an improvement upon general flocks similar

to that which gives the high values to Australian sheep. The extreme Australian prices are paid by breeders of stud sheep and are rendered possible by the patronage of a large number of owners of large commercial flocks who know that \$500 or \$1,000 invested in an exceptional ram is more than returned in the fleece values of the great number of sheep tracing descent to such a ram in a few years. Not only this, but improved breeding qualities of the ewes, aside from their wool yield, are highly appraised, because the owner is reasonably certain to continue in the business, market his product in a way to secure its maximum value, and control enough money for investments in connection with his business.

The type and character of sheep in many of the prominent stud flocks is so well known and the confidence in the breeders is such that a large proportion of the sales of rams for flock use and some sales of stud rams are made without examination by the buyer. Some time before the ram-selling season breeders of rams class their offerings according to quality. Rams worth \$20, \$30, or \$40 are drafted into corresponding lots. Higher-priced rams are sold singly or upon examination at home or at public sales. Buyers of the classed flock rams state what price they wish to pay, and the number required is drawn from the lot of the price named. In some studs an outside expert is employed to class the rams to be sold. Such a classer may also divide the breeding ewes into uniform lots, for which the owner selects suitable rams.

MUTTON BREEDS.

The use and popularity of the mutton breeds in Australia is on the increase, owing to increasing demands of the meat trade and of farmers who buy sheep to fatten for the market. The president of the New South Wales Sheep Breeders' Association stated last year that in 10 or 15 years more than half the sheep of that State will be crossbreds. The term "crossbreds," as used in Australia, includes all sheep other than Merinos or those carrying a preponderance of Merino blood.

On account of the greater length and weight of wool and greater body weights when grown out, the long wools are used most for crossing by those who expect to keep the crossbred lambs until shorn. The Lincoln, Border Leicester, English Leicester, and Romney Marsh are all in demand. The Cotswold is little known. The down breeds are favored most by those who market their lambs before they are a year old, and of these breeds only the Shropshires and South-downs can be said to be widely known.

The Corriedale is gaining ground in Australia. An organization of breeders of Corriedales was effected at Sydney in 1914, and provisions made for founding a flock book. Sixty-seven stud and flock

rams sold in the 1914 Sydney sale at an average of \$42 per head. During the same week one commission firm sold sheep of various breeds at the following average prices per head: 50 Shropshire flock rams at \$8; 694 Lincoln stud and flock rams and ewes at \$20; 551 Border Leicesters (mainly flock rams) at \$28; and 450 Romney Marsh stud and flock rams and ewes at \$25.

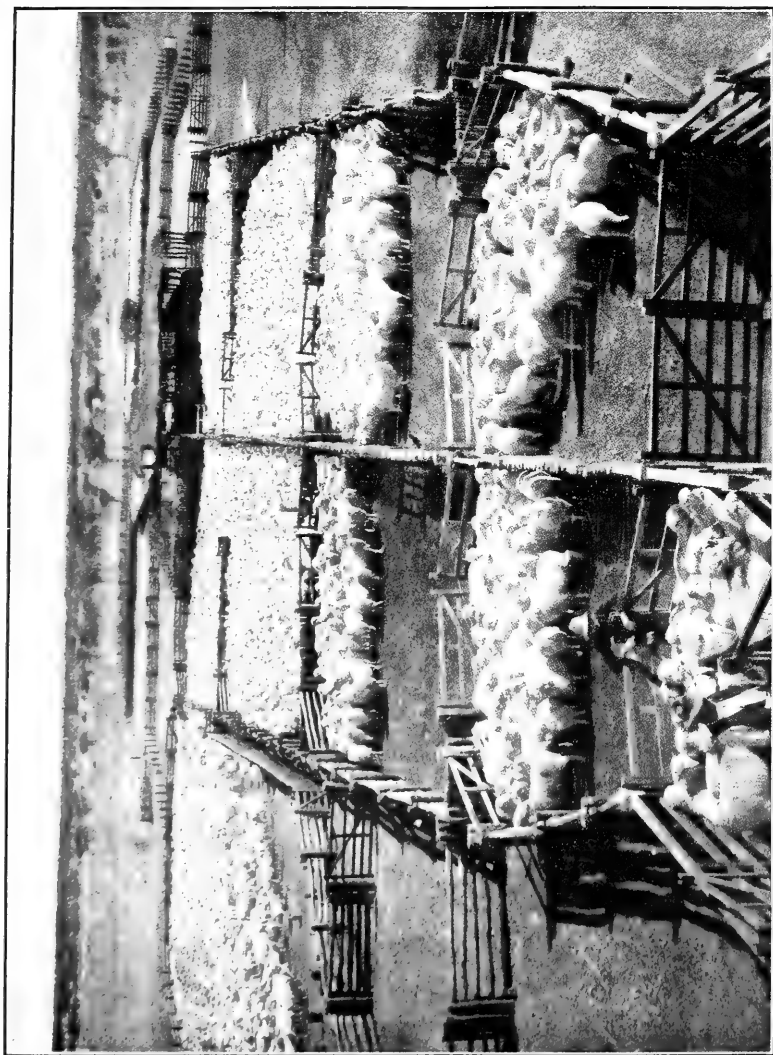
SHEEP BREEDERS' RECORDS.

While American and Australian sheep breeders seem earlier to have been in agreement as to the points of wool-producing sheep, in the last quarter of a century their ideas have diverged. In contrast to the requirements of registration and the multiplicity of flock books in the United States the great Australian Merino sheep-breeding business still progresses with only private records. These private records are in some cases fairly complete but very seldom permit the full tabulation of a pedigree for three generations. In selling rams at from \$2,000 to \$5,000, which is commonly done, the descent or immediate parentage is a consideration, but is vouched for only by the breeder, which is really the only guaranty received by the purchaser of any animal having its pedigree entered in an association's registry.

SHOW SHEEP.

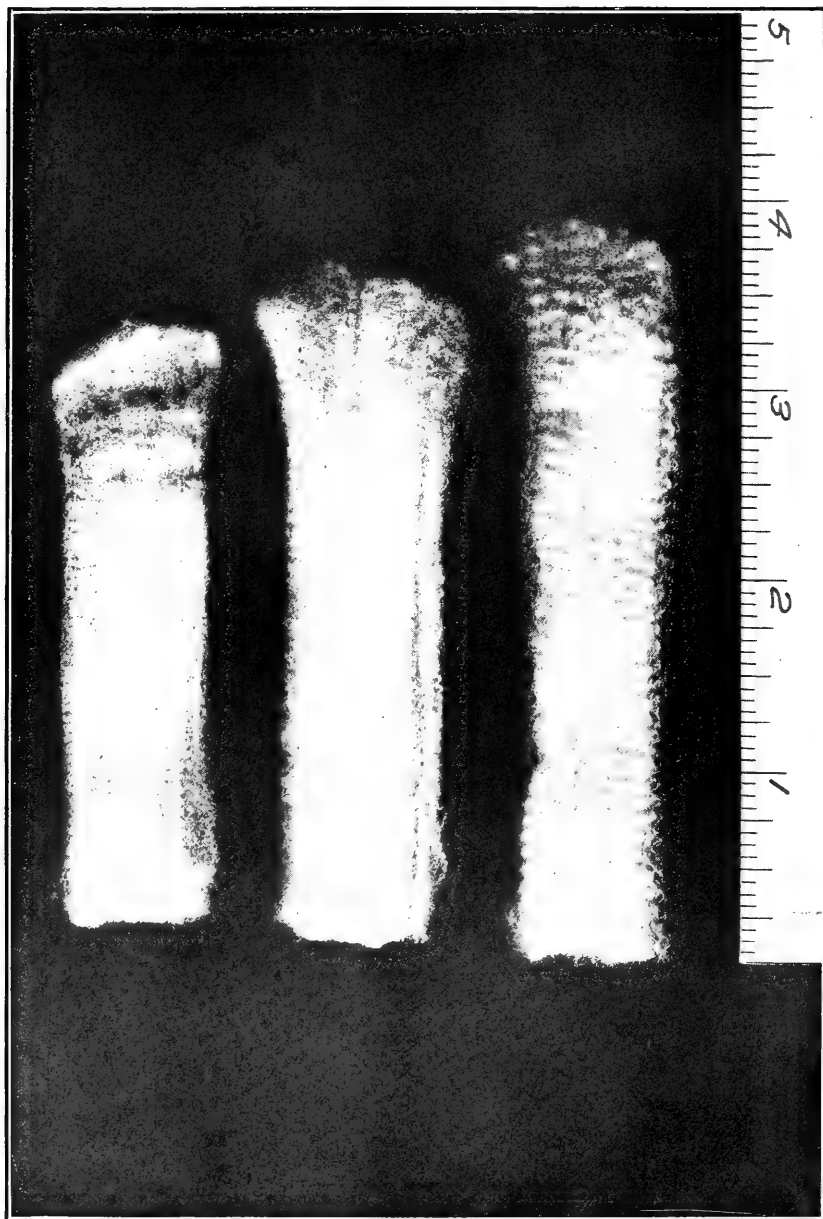
Show-ring results apparently carry little weight with Australasian sheep breeders. Their regard for a line of breeding or for any particular flock is based upon the sale of wool shorn from the offspring of representatives of such strains or flocks. Australian show managers seem to have succeeded somewhat better than those in America in having fine-wool sheep exhibited fairly. Evidences and claims of early or stubble shearing are not missing, however, and stud breeders whose flocks are well established prefer to offer their stock for sale without showing. In the Sydney annual show and sales sheep not exhibited usually sell higher than the prize winners.

Having once secured satisfactory results by using rams from a particular stud flock the commercial sheep raiser is assured that other rams from the same stud will possess and transmit the same general qualities. This is especially true in Australia because the older stud flocks make but limited, if any, use of sires bred on other stations. The American breeder's insistence upon an outcross in each generation finds its opposite in the Australian's preference for stud sires of his own breeding. Of course the size of the flocks renders it possible to avoid very close matings. In some cases carefully bred stud flocks have retained their vigor for over 20 years with practically no outside blood.



DRAFTING YARDS ON AN AUSTRALIAN STATION.

The picture shows a flat-topped canopy in the center of the yards, under which the main cutting chute is located.



REPRESENTATIVE SAMPLES OF AUSTRALIAN "FINE," "MEDIUM," AND "ROBUST"
WOOL.

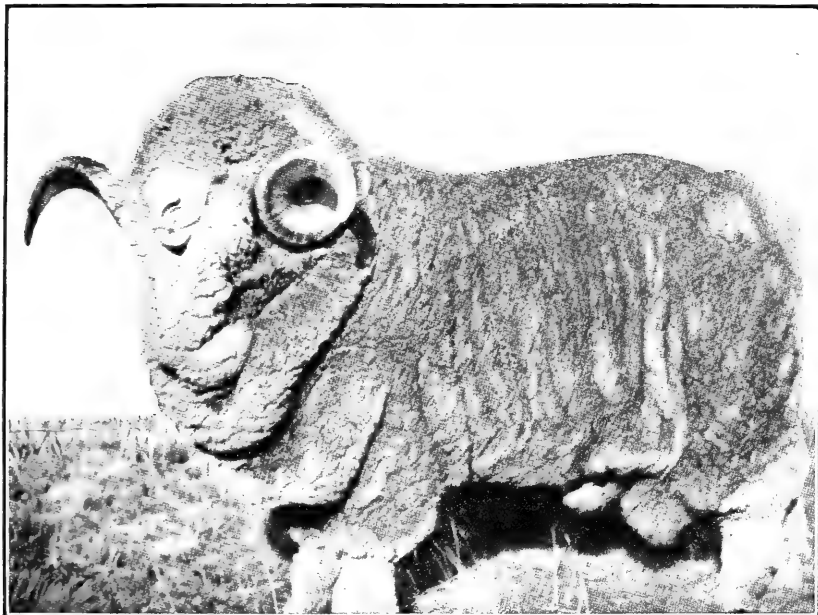


FIG. 1.—THE TYPE OF MERINO RAM LARGELY BRED IN TASMANIA.

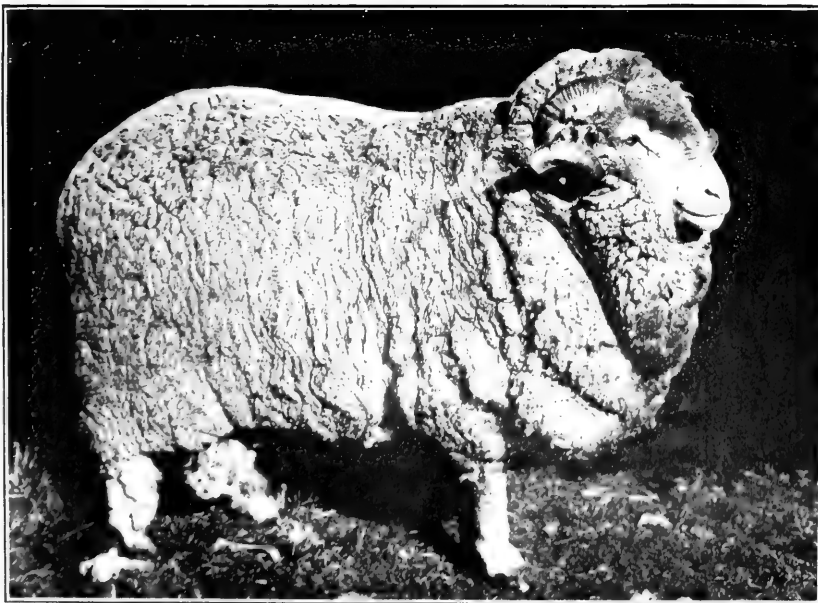


FIG. 2.—THE TYPE OF MERINO RAM NOW POPULAR IN AUSTRALIA OUTSIDE OF TASMANIA.



FIG. 1.—A GROUP OF CORRIEDALE RAMS AT THE 1914 SHOW AT CHRISTCHURCH, NEW ZEALAND.



FIG. 2.—SHORN CORRIEDALE YEARLING RAMS.

BREEDS AND TYPES IN NEW ZEALAND.

From a total of 15,000,000 sheep in 1886, New Zealand flocks have increased steadily to 24,500,000 in 1914. A part of this increase is due to breeding for mutton, as well as wool, instead of the almost exclusive aim to produce wool before the exporting of meat became common. While wethers are still kept until 3 or 4 years of age in some sections, the number of breeding ewes is now about 12,500,000, an increase of 3,250,000 breeding ewes since 1904, during which time the total number of sheep increased by 6,000,000. The following paragraph from the New Zealand Official Year Book for 1914 explains the status of the various breeds:

The Dominion is eminently suited for sheep breeding, practically every description of sheep finding a favorable local habitat. In the hilly and down country of the South Island the Merino has been bred for very many years, and was the original sheep depastured. In fact, the Merino ewe furnished the foundation of the cross-bred stock which has made Canterbury mutton famous on British meat markets. In the early days of the Canterbury meat trade the English Leicester of the original type was the favorite ram for putting to the Merino ewe. Of later years the Lincoln has been largely employed to cross with the Merino, and black-faced rams have been further employed to put to the cross-bred ewes. In the North Island the Romney sheep, which suits the rather moist climate of this portion of the Dominion, has become the most popular sheep; it is also increasing in numbers in the South Island. The Lincoln and Border-Leicester are also favored in both islands, while the Southdown is displacing other breeds for fat-lamb production right throughout the Dominion. The Leicesters, mainly the English variety, are still the most popular British breed in the South.

With a total of 11,625,000 sheep in the South Island in April, 1914 (lambs are dropped mainly in September and October¹), there were 85,299 breeding ewes in 491 registered flocks, distributed as follows:

Breed.	Number of flocks.	Ewes bred in 1914.	Breed.	Number of flocks.	Ewes bred in 1914.
Border Leicester.....	158	19,910	Corriedale.....	22	11,010
English Leicester.....	113	17,937	Merino.....	15	7,399
Romney Marsh.....	85	15,110	Lincoln.....	14	1,861
Southdown.....	46	4,989	Ryeland.....	3	159
Shropshire.....	34	3,525	Half-bred.....	1	3,399

THE CORRIEDALE.

The study of Corriedale sheep and the selection of a trial importation were the main objects of the writer's visit to New Zealand. The Corriedale breed was produced and is still most extensively bred in the Province of Canterbury of the South Island of New Zealand.

The Corriedale sheep, as now bred in New Zealand, is a wool and mutton sheep. Its breeders seem to have given special emphasis to wool, most of which would grade on our market as three-eighths blood and commonly has a length of 6 inches. At the Christchurch

¹ Corresponding to March and April in the Northern Hemisphere.

show prizes are offered for Corriedale sheep entered in the wool and mutton competition. The following rules govern this competition:

For the purpose of this competition the definition of Corriedale to be as follows:

To be the progeny of half-bred rams from half-bred ewes, and the result of not less than 15 years of in-breeding, and showing a decided fixed type of half-bred sheep, the original stock to be the progeny of Merino and long-wool sheep of any pure breed.

The breeding of the rams to be stated at time of entry.

Each exhibitor will be required to enter three Corriedale ram hoggets; all rams to be bred by exhibitor.

The rams will be taken charge of by the committee, shorn and grazed as the committee may deem desirable, but at the owner's risk. The rams will again be exhibited at the association's show the following year; they will be shorn by the committee, the fleeces being carefully weighed and afterwards valued in the grease by an expert.

The shorn rams will be judged by fat-sheep judges, who will be asked to fix the value of the sheep from a mutton point of view.

The ram showing the greatest money value, carcass and wool taken into consideration, to be the winner.

The following tabulation of the results of the 1914 competition shows the weights and quality of the fleeces and the carcass values:

Corriedale wool and mutton competition, 1914.

Ear tag.	Weight of fleece.		Weight of pieces.		Total weight of wool.	Value per pound, fleece.	Value per pound, pieces.	Value of fleece.	Value of pieces.	Total value of wool.	Wool valuer's remarks.	Value of mutton.	Total value.
	lb.	oz.	lb.	oz.	lb. oz.								
2..	12	11	3	5	16 0	\$0.26½	\$0.15½	\$3.56	\$0.51	\$3.87	48s.....	\$6.60	\$10.47
8..	12	10	4	1	16 11	.27	.16	3.41	.65	4.06	50s.....	6.36	10.42
6..	11	3	3	1	14 4	.26	.15½	2.91	.47	3.38	48s.....	6.96	10.34
15..	15	2	5	12	20 14	.25½	.15½	3.86	.99	4.75	50s, 56s..	5.52	10.27
1..	10	2	4	1	14 3	.27	.15½	2.73	.63	3.36	48s, 50s..	6.84	10.20
3..	13	1	4	5	17 6	.27	.15½	3.53	.67	4.20	46s.....	6.00	10.20
16..	12	1	4	9	16 10	.26½	.16½	3.20	.75	3.95	56s.....	6.00	9.95
4..	14	6	3	3	17 9	.27	.15½	3.88	.49	4.38	46s.....	5.52	9.90
14..	12	5	3	9	15 14	.26	.16	3.20	.57	3.77	50s.....	6.00	9.89
18..	12	10	5	4	17 14	.26½	.16½	3.35	.87	4.21	50s.....	5.64	9.85
17..	11	8	5	4	16 12	.27	.16½	3.10	.87	3.97	50s.....	5.82	9.79
11..	12	2	3	14	16 0	.27	.16	3.27	.62	3.89	50s good..	5.88	9.77
13..	11	8	4	12	16 4	.27	.16	3.10	.78	3.86	50s, 56s..	5.76	9.62
7..	11	13	3	4	15 1	.25	.15½	2.95	.50	3.46	46s, 50s..	6.12	9.58
5..	12	7	3	2	15 9	.27	.16	3.36	.50	3.85	50s.....	5.64	9.50
9..	12	11	3	8	16 3	.27½	.16	3.49	.56	4.05	50s, 56s..	5.40	9.45
10..	10	15	4	4	15 3	.26	.16	2.84	.68	3.52	50s.....	5.88	9.40
12..	11	2	3	14	15 0	.25½	.16	2.84	.62	3.46	50s.....	5.04	8.50

The illustrations give a fair idea of the general appearance of Corriedale sheep, though not many representatives have the carcass development of those shown with their fleeces removed. On the average the carcasses have much the same development as is shown by lambs from Merino ewes and sired by rams of the long-wool breeds in this country. A good many lambs of Corriedale breeding are marketed around six months of age and shipped with first-cross lambs as "Prime Canterbury." Old or cast Corriedale ewes are commonly bred to mutton rams to produce carcasses of higher value, the ewes themselves then being fattened and sold.

The development of the Corriedale started with the crossing of Lincoln and English Leicester rams upon Merino ewes to produce lamb carcasses for export. Finding that ewes of such breeding were profitable in some sections, attempts were made to create flocks that would breed true to the type shown by the half-bred of the first cross. Half-bred rams were mated with half-bred ewes, the ewe progeny very severely culled (sometimes only 25 per cent were retained) and again mated to selected half-bred rams, usually of the same generation and also from the same flock. This continued inbreeding of half-breds, accompanied by careful and strong culling, has produced a class of sheep, which, as has been said, compare favorably with other breeds in respect to uniformity and trueness to type, as shown by evenness in separate flocks or similarity of different flocks.

The following flock histories printed in the appendix of volume VII of the South Island Flock Book, published by the council of the New Zealand Sheep Breeders' Association, relates the essential features in connection with three of the 17 Corriedale flocks entered in that volume:

CORRIEDALE FLOCK. THE PROPERTY OF JAMES LITTLE.

Mr. Little commenced experimenting with the view of producing inbred half-bred sheep when he was manager for the late Dr. Webster, proprietor of the Corriedale estate, Otago. Romney Marsh and Merinos were first used. The result was entirely satisfactory and would have been continued but for the decease of that gentleman and the sale of the property. On his taking up the Allendale estate, Waikari, Mr. Little continued to experiment.

In 1879-1880 he put 4,000 large-framed high-class Merino ewes to Lincoln rams, bred by Mr. Sutton and some of the late Dr. Webster's strain. From 100 of the best ram lambs, the progeny of these ewes, a heavy cull was made, when 20 of the best were retained for service. These were mated with a pick of the half-bred ewes, the progeny of the Merino ewes and Sutton and Webster rams, the result being a very high-class type of half-bred sheep. In 1890 two rams bred by Mr. Tanner from Merino ewes and Lincoln rams were used, but the result was not considered satisfactory. About the same time 20 stud Merino ewes were purchased from Mr. D. Rutherford and the same number from the Horsley Downs flock. By this means fresh blood was procured and was kept going on the line breeding until 1902, when a Corriedale ram was procured from Mr. James Stringfellow. In 1909 a ram was used bred by the New Zealand and Australian Land Co. (Moeraki estate). The rams used in the flock, with these exceptions, have all been descended from "Old Jonathan," bred by Mr. Little 20 years ago.

In 1903 the flock was transferred from Allendale to Dalmeny.

Returns for 1911.

Ewes, four-tooth and upwards, put to ram-----	598
Shearling ewes put to ram-----	260
Total -----	858
Lambs bred in 1910—Rams, 421; ewes, 483.	
Sires used in 1911, bred by owner.	
Rams sold—Two-tooth, 131.	

CORRIEDALE FLOCK. THE PROPERTY OF THE NEW ZEALAND AND AUSTRALIA LAND CO. (LTD.)

This flock was founded by Mr. W. S. Davidson, at the New Zealand and Australian Land Co.'s Levels Estate, in 1874. One thousand Merino ewes were put to Lincoln rams, and out of the produce of these ewes 150 half-bred ewes were selected for mating with rams, also out of the same ewes.

Since 1874 the progeny of these ewes have been inbred with rams out of the same flock. The only outside blood introduced was a ram bought in 1892 from Mr. Tanner, Hawke's Bay (who had then an inbred flock started about the same time as the Levels Estate flock), and one ram from Messrs. Reid Bros., Darfield, in 1902, but these two rams were very slightly used. In 1904, when the New Zealand and Australian Land Co. gave up the Levels Estate for closer settlement, some of the Levels Estate Corriedale flock was transferred to the New Zealand and Australian Land Co.'s Moeraki Estate at Hampden, where its breeding has been continued on the same lines as in previous years, and no outside blood has been introduced into the flock since it was transferred to that property.

Returns for 1911.

Ewes, four-tooth and over, put to ram-----	391
Shearing ewes from own flock put to ram-----	500
Total -----	502

Lambs bred in 1910—Rams, 231; ewes, 257.

Sires used in 1911, bred by owner.

Rams sold—Two-tooth, 223; four-tooth, 4.

CORRIEDALE FLOCK. THE PROPERTY OF C. H. ENSOR.

This flock was founded by the late Charles Ensor, of Mount Grey, in the year 1889, by mating fine-combing stud Merino ewes with English Leicester stud rams. The progeny were then inbred for a number of years, the only outside blood used being rams from the New Zealand and Australian Land Co.'s (Levels) Corriedale flock, and later from the same flock but bred on the company's Moeraki Estate. The leading sires have been bred in the flock.

In 1901 the flock passed into the hands of Ensor Bros., who continued to carry on the flock and to follow the lines of breeding of the founder.

In 1906 and the following year nearly the whole flock became the property of C. H. Ensor. It was then removed to Mount Grey, White Rock.

Returns for 1911.

Ewes, four-tooth and over, put to ram-----	2,100
Shearing ewes from own flock put to ram-----	500
Total-----	2,600

Lambs bred in 1910—Rams, 1,080; ewes, 1,150.

Sires used in 1911, "Quality," "Premier 4th," "Model," "Jimmy," and others bred by owner; "Samson," bred by New Zealand and Australian Land Co.; others bred by G. D. Greenwood and C. N. Orbell.

Rams sold—Two-tooth, 419; four-tooth, 20.

As to the Merino's share in forming the Corriedale there need be no question. It would be impossible to state accurately whether the breed is indebted most to the English Leicester or to the Lincoln. The question is not of great moment, since the Lincoln was itself improved by the English Leicester at one time. In the English



FIG. 1.—A GROUP OF MERINO RAMS FROM ONE FLOCK SOLD BY AUCTION AT SYDNEY IN JULY, 1914, AT AN AVERAGE OF \$1,770, THE RAM ON THE RIGHT BRINGING \$5,000.

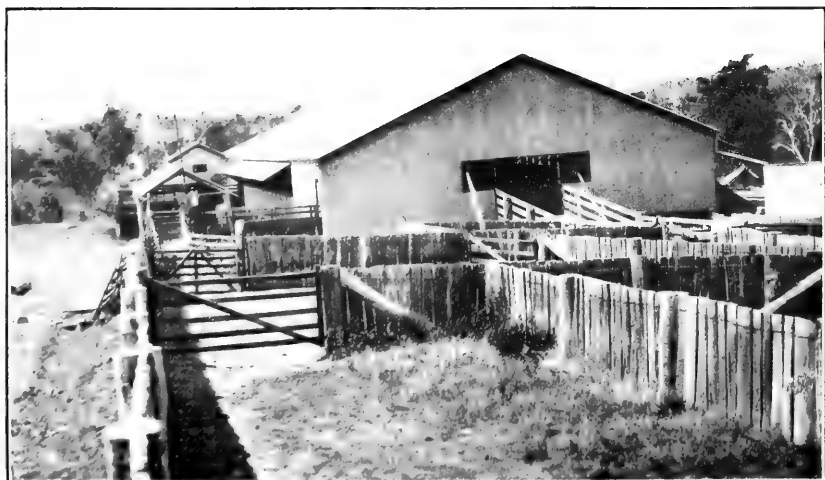


FIG. 2.—A QUEENSLAND SHEARING SHED THAT TURNS OUT ONE OF THE HIGHEST SELLING CLIPS IN THAT STATE.

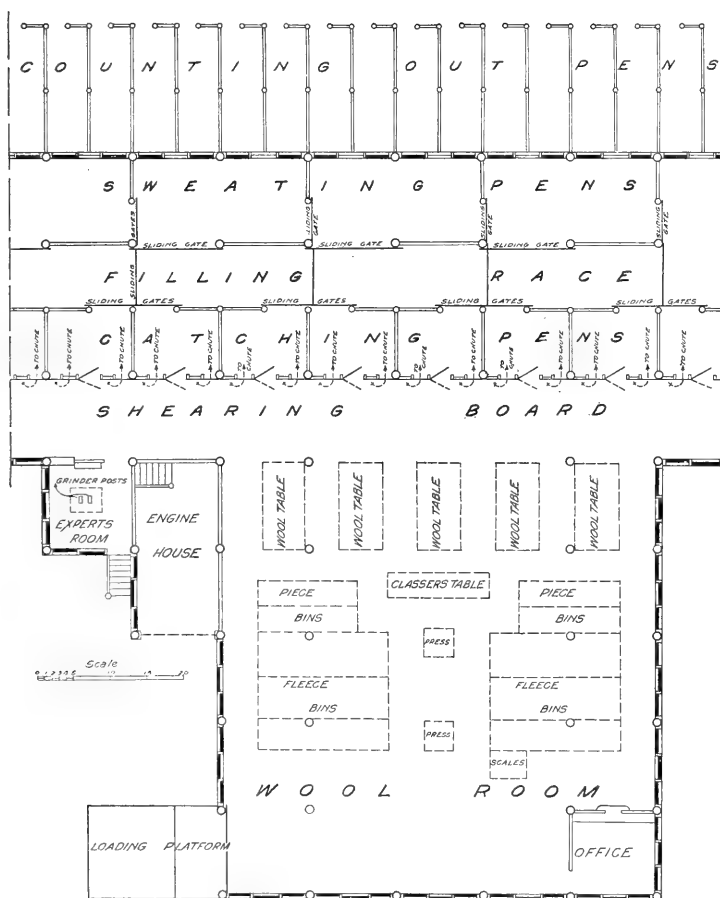


FIG. 1.—WOOL ROOM OF A NEW SOUTH WALES SHEARING SHED.



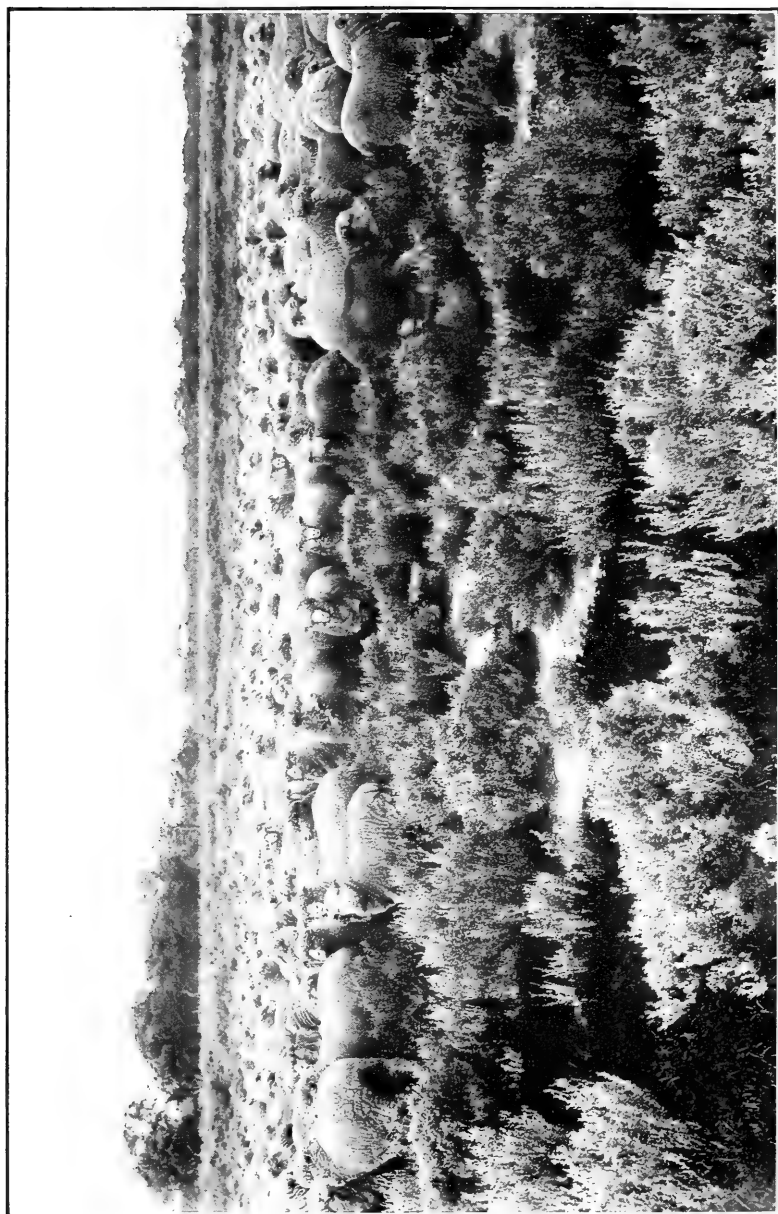
FIG. 2.—BALING ROOM IN AN AUSTRALIAN SHEARING SHED.

An end of the classer's table shows in the space between the wool bins at the left.



PLAN OF WOOL ROOM AND SECTION OF SHEARING BOARD OF AN AUSTRALIAN SHEARING SHED.

The sweating pens, filling race, and catching pens are built sufficiently high from the ground to permit shorn sheep discharged through the schutes to pass underneath to the counting pens, which are outside the building.



NEW SOUTH WALES MERINO EWES AND LAMBS.

Leicester and Merino are two breeds less mixed in their earlier ancestries and bred for their particular improved qualities for a longer time than any other breeds of sheep. Flocks containing all three lines of blood compare favorably with those containing only two, though breeders whose sheep have none of the Leicester blood claim heavier shearing qualities and greater vitality, to which latter claim objections are not wanting.

Even among New Zealand breeders of Corriedales there is strong preference for the "stronger" wools, the reason assigned being practically the same as those quoted from Australian Merino breeders in an earlier part of this report.

The character of country upon which the Corriedale is bred in New Zealand varies from level and fairly rich artificial grass pastures to rough hills with altitudes around 3,000 feet, on which snow sometimes lies for several months at a time. At its worst the feed is better than that produced on many of the dry-range areas of the United States. The breed's greatest promise of usefulness in this country is for those localities which need and which can support sheep of more carcass development than the Merino has, and in which the wool is to be relied upon for at least one-half of the flock income. Owing to the paddock system of grazing sheep in New Zealand, selection has not regarded the herding instinct that ordinarily shows in sheep having one-half Merino blood. The experiments which the Bureau of Animal Industry will conduct with this breed will be designed to test the herding instinct of the breed, its ability to thrive on various types of western ranges, and the extent to which it can impress its features upon the sheep bred in the sections where it seems desirable to raise a sheep such as the Corriedale now is.

SHEARING AND WOOL CLASSING.

The practices of American and Australasian woolgrowers differ more in respect to the handling of the shorn wool than in any other part of their work. In the United States the wool is not infrequently sold before it is shorn. Even when it is to be sold after shearing the sheep are not sorted for shearing and the entire fleeces are sacked just as they run. In disposing of the wool there is no possibility of fixing a price upon the amount of each of the various classes of wool in the sacks, but bargaining must be done upon the basis of the clip as a whole. The clips are usually sold to traveling representatives of houses located near the manufacturing centers. Manufacturers may send their buyers to buy direct from the woolgrowers, but most of the concerns buying in the field assemble numerous clips and sell to mills in large lots from their warehouses. While in the dealers' hands many, and in some years most, of the clips are opened

up and the fleeces, without being untied, are graded and placed in large piles awaiting sale.

Practically all of the Australian and New Zealand wool remains the property of the grower until it is sold to the manufacturer. The cost of actually shearing the sheep constitutes only about one-half of the amount expended in preparing the wool. The main result of this extra labor and trouble is to divide the clip into various lots, each of which is so uniform within itself that the buyer knows by examination of a single bale whether or not the lot is of the grade and quality of wool he needs, and is also sure that there will be in a lot purchased a minimum amount of wool differing from what the lot was supposed mainly to consist of. This gives certainty to the transaction and renders possible the Australasian system of selling wool through commission brokers to mill buyers. Independent operators may buy wool to sell again, but the bulk of the offerings go direct from the warehouses of the selling agents to the mills. As a result of this plan the report of sales received by a grower shows the selling price of each of the lines into which the classer divided the clip.

In view of the present interest in this country in improving the preparation of wools for market, it may be of advantage to discuss the more distinctive features of the Australasian system.

It is not yet time in this discussion to consider the practicability of having American wools classed as are Australian wools, or the probability of the growers' profiting thereby in the event of their becoming convinced that they can and should adopt the essential features of the Australian method of handling wool at the shearing shed.

RELATION OF WOOL CLASSING TO BREEDING.

The part that wool classing plays in promoting better breeding is of great importance. This phase of the matter is well expressed by a contribution to the Pastoral Review of January, 1915, page 135:

The classification of his wool at shearing time is the woolgrower's annual indication of the progress he is making as a breeder, for it shows him whether he is increasing the proportion of the higher qualities of wool and at the same time decreasing the proportion of the lower grades, and whether he is thus making his flock more profitable. If, therefore, the Australian woolgrower abandoned the classing of his clip he might just as well abandon all the other little points in sheep management the observance of which has done so much to place the wool industry where it is.

He has spent huge sums of money on the best class of rams he can afford, on subdivision, and other improvements that are necessary for improving his sheep by selection, and he has done this so that year by year he will see his proportion of high-grade wools increase and his proportion of low-grade wools decrease. Is it likely, then, that at shearing time he will jumble all his fleeces up into a confused heap and bury beneath locks, stained pieces, necks, burry breeches, and bellies all the beautiful, clean, shafty wool he has managed to grow on the back and sides of his sheep?

Experience tells them whether fine, medium, or robust wool stands their particular climatic conditions best, and experience also tells them the most profitable limit as regards length of staple. Having the right type of wool fixed in their eye, the Australian sheepmen, by the process of selection, endeavor to get as much of that type of wool as they can throughout their entire flocks. By care and skill, exercised for many years, a large number of breeders have brought their flocks to a wonderful standard of uniformity. * * *

THE WOOL FROM THE SHEEP TO THE BALE.

An idea of what is required in preparing wool to secure the advantage of full preparation can best be gained by following a clip from the shearing shed to its final sale.

The sheep come to the shearing shed in uniform bands. Long-wool and crossbred sheep never run together, neither is either type mixed with Merino sheep. With mature sheep it is unnecessary to sort immediately before shearing except to separate lambs or a few strays. Young sheep are carefully classed before their first shearing and remain in the same uniform lots during their stay on the station. This uniformity in the single lot of sheep does not mean that all the fleeces go into one class. It means that the classer will have to deal at one time only with fleeces of the same general type and that by examining the sheep and studying the first few fleeces brought up he can determine how the wool should be divided up to bring the greatest total returns when sold.

Great care is exercised to keep the wool in good condition. At one Queensland shearing shed the ground from the approach to the pens to the shed door is sprinkled with water to prevent dust from rising and settling upon the sheep. The holding pens all have slatted floors so that even if the sheep lie down no dirt adheres and the wool is not soiled.

The shearer first removes the belly wool, separating it as a single piece from the fleece, when it is carried to the bin provided for "bellies" near the baler. When the rest of the fleece is removed it is picked up by a boy who carries it to a slatted-topped table in the wool room, and while retaining his hold upon the thigh wool, throws the fleece into the air and away from him in such a way that it falls upon the table fully spread out, flesh side down, as shown in Plate VI.

SKIRTING AND ROLLING.

The fleece is now skirted. Two men, one on each side of the table, remove the tags, "britch" wool, and discolored, sandy, or burry wool from the lower sides and as much as may be necessary from the neck. In some well-bred sheep it may not be necessary to go very deeply into the britch. While the skirters must use their judgment for each fleece as to how much to remove, either from the thigh, side or neck, their work is directed and supervised by the wool classer, who has charge of the wool after it reaches the wool room.

After skirting, each man turns his side of the fleece in toward the center and one turns back the neck end while the other turns the other end in toward the neck end. The fleece is then rolled up from the breech forward, making it into a neat bundle, which is then carried to the classer's table.

PIECE PICKING.

Before discussing the work at the classer's table, it will be best to follow the skirtings further. The wool dropped to the floor by the skirters is carried to the table of the piece picker. Ordinarily the piece picker makes three lots from what comes to his table—stained wool; first pieces, which consist of the lightest and cleanest pieces; and the inferior or second pieces. These three kinds of pieces are taken to corresponding bins convenient to the baler. If heavy dung locks are present they are thrown into a pile at one side until the wool can be clipped off during odd times or on wet days. In some cases, when it is necessary to remove considerable burry wool from the neck, this goes to the bin for broken fleeces and may also first have some pieces removed from it. The floor sweepings go over the piece picker's table. The bellies commonly go direct to their bin in the baling room, though preferably the discolored wool is taken out as stained pieces, particularly in handling wethers' wool. The second cuts, sweat locks, etc., that fall through the wool tables are baled as locks. The number of bales of bellies, pieces, and locks resulting from this work averages around one-third of the total number in the clip. It is claimed in some cases that the extra value received for pieces by having them assorted is sufficient to pay for the labor of the wool room.

WOOL CLASSING.

Most interesting, though perhaps not always most important, of all, is the work of the classer or grader, as he would be known in a United States warehouse. His table is located convenient to the bins from which the balers take the wool, and faces in such a way as to give him a view of the work at the tables. He directs and is responsible for the work of the skirters and rollers, piece pickers, and balers. He receives the rolled fleeces at his own table and must assign each to its proper class. The number of classers and their designation depend upon the size and character of the clip. It is regarded as always desirable that the best lot should be the largest and that as few classes as possible should be made. At the same time a fleece that is tender or otherwise inferior is never placed with better fleeces to avoid making another class, as its presence would destroy the buyer's confidence in the classing of the whole clip.

This point is presented by a large wool-selling commission house in the following suggestions:

Avoid overclassing, and, consistently with evenness, length, condition, and quality, make the lines as large as possible. The best average prices for the whole clip are usually secured when the biggest line brings the biggest price.

Our recommendation is to skirt lightly and make the top lines of the fleece as large as possible, so as to get the best average price for the whole of the clip, which, after all, is the true index of the value realized for the wool.

Another Australian authority says:

A system of classing which applies generally to Merino clips * * * consists in classing—

(a) According to the length and strength of the staple.

(b) The "condition" of the wool, i. e., the amount of yolk or grease, and the quality of earth or sand and vegetable matter (such as burrs, seeds, etc.) in the fleece.

(c) Color and general characteristics of the wool.

Regarding classing crossbred wool the same authority says:

It is in consequence of this variation (from 36's to 56's in fineness) that it is necessary in classing crossbred to take so largely into account the fineness or coarseness of fiber, but at the same time condition, color, and the general appearance of the wool must not be forgotten.

The classing of the 1913 clip from a New South Wales flock of 7,000 head composed of ewes, hoggets (yearling ewes), and rams is shown. It possibly represents overclassing, though it was considered imperative to keep rams', ewes', and yearlings' wool separate.

Classing of the 1913 clip from a flock of 7,000 head.

Brand. ¹	Number of bales.	Description of wool.	Price per pound at which sold.
			<i>Cents.</i>
A comb. E.....	17	Bright, clean wool with good length and character	21
A comb. EH.....	4	do.	22
A comb. R.....	3	do.	20
AA comb. E.....	29	Second to A comb. E; shorter with more condition.....	20
AA comb. EH.....	5	Second to A comb. EH; shorter with more condition.....	18
AA comb. R.....	1	Second to A comb. R; shorter with more condition.....	16
A fleeces E.....	8	Bright, with good length, but tender.....	18
A fleeces EH.....	2	do.	18
S comb.....	4	All strong fleeces	20
Fleece E.....	6	Short and heavy conditioned fleeces (yellow).....	17
Fleece EH.....	2	do.	17
Fleece R.....	2	do.	16½
Broken E.....	21	Necks and bulky pieces with very little burr and seed.....	18½
Broken EH.....	5	do.	21
Broken R.....	2	do.	20
A pieces E.....	29	Second to broken E and heavy with burr and seed	20
A pieces EH.....	9	Second to broken EH and heavy with burr and seed	17
A pieces R.....	4	Second to broken R and heavy with burr and seed	14½
Bellies E.....	7	.....	13
Bellies EH.....	2	.....	13
Bellies R.....	1	.....	11
Stained pieces.....	1	.....	8
Locks E.....	6	.....	6
Locks EH.....	2	.....	6
Locks R.....	1	.....	5
A lambs.....	1	Best of lambs, good length with very light burr.....	19
AA lambs.....	5	Shorter than A lambs, with a little burr and seed.....	11½
AAA lambs.....	6	Very short and heavy with burr and seed.....	7

¹ E=Ewes. EH=Ewe hoggets. R=Rams..

At a Queensland shed, where 10,000 2-year-old wethers were shorn, the following classes were made:

1. AAA combing. This lot contained only the finer, best fleeces, having good length, sound, bright, and light shrinking.

2. AA combing. Similar to AAA combing, but heavier in tips, and would shrink more on that account.

3. AA. Similar to AA combing, but shorter.

4. A. Short-stapled and heavy in yolk.

5. AA fleece. Rougher and coarser than AA combing.

6. A fleece. Short, discolored.

7. Broken fleeces. Best parts of neck and britch wool from skirtings.

8. First pieces. Best and cleanest of skirtings that remain after separation of that going into broken fleeces.

9. Pieces. Sometimes called second pieces; dirtier and inferior to first pieces.

10. Locks. Second cuts and sweaty locks from below the wool table.

11. Bellies.

The wool bales are branded with the classer's designation of their contents and so entered in the auction-sale catalogue. It will be noticed in the latter case that the best wool was called AAA combing, and AA combing was not so good. In the New South Wales clip referred to the A grade is higher than AA. This causes no confusion, because the buyer depends for his estimate upon his examination of sample bales, and his chief concern in regard to the classing is to know that the skirting was properly done, and that there is uniformity throughout each bale and throughout the various bales in the lot as offered in the sale.

It is the aim to avoid, as far as possible, the selling of too many lots of less than 10 bales. As a rule a 50-bale lot will bring more per pound than a 5 or 10 bale lot of similar wool. It takes the buyer as long to value a small lot as a large one, and, if purchased, the smaller lot only partially fills an order for several hundred bales.

A lot of three bales or less is sold as a "star" lot, either at a different time or in a different place from the selling of the large lots. Selling houses sometimes "interlot" what would otherwise be star lots. Small lots of wools of the same kind and considered to have the same money value are combined to form a larger lot, and settlement with each consignor interested in the joint offering is made at the price realized for the interlotted offering.

Report of a wool sale at Sydney in April, 1914.

Lot.	Mark.	Description.	Bales.	Price.
GREASY.				
1	H/Nandawar (from Boggabri).....	Lbs.....	12	d. 64
2	Lumley Park/C (from Goulburn).....	X-B Lbs.....	9	103
3	Tabratong (from Nevettire).....	Pcs.....	16	23
4	IJH/NZL (from Braidwood).....	MW.....	6	93
5	~Jh/New England (from Inverell).....	F.....	5	113
6	Tyrie (from Dandaloo).....	Pcs.....	14	3
7	E/Lora Downs (from Coonamble).....	AAE.....	10	-----
8	Willara (from Wanaaring).....	F.....	8	9
	No lot 9.			
10	DD/Lisgar (from Parkes).....	1 E and H.....	25	-----
11	do.....	1 W.....	9	-----
12	do.....	1 Pcs.....	10	92
13	DP (from Monaro).....	E and H.....	6	94
14	+a/Kentucky (from Queanbeyan).....	E and W.....	7	101
15	JP/Marysville (from Goulburn).....	M.....	14	113

Report of a wool sale at Sydney in April, 1914—Continued.

Lot.	Mark.	Description.	Bales.	Price.
GREASY—continued.				
16	JP/Marysvale (from Goulburn)	M.....	7	10 ³ / ₄ d.
17	WJM (from Goulburn)	ME.....	6	11 ¹ / ₂
18	MD/Hill/Station in oval (from Queanbeyan)	1 Com E.....	18	11 ¹ / ₂
19	do.....	A Com E.....	9	10 ³ / ₄
20	do.....	F.....	6	9 ¹ / ₂
21	Auburn Vale/Ans (from Inverell)	Lbs.....	12	8 ¹ / ₂
22	Euambeline (from Nyngan)	AA Lbs.....	6	7 ¹ / ₂
23	do.....	A Lbs.....	7	5
24	JMD/Urarra (from Queanbeyan)	BE.....	7	10 ¹ / ₂
25	do.....	X-B and X-B E.....	6	9 ¹ / ₂
26	Ahn in dia./Cooyah (from Springsure, Q.)	AAA W.....	7	13
27	do.....	AAAAE.....	11	12 ¹ / ₂
28	do.....	AAW.....	9	11 ¹ / ₂
29	do.....	AAE.....	11	11 ¹ / ₂
30	do.....	AA Pcs E & W.....	11	10 ³ / ₄
31	do.....	AA Lbs.....	8	11 ¹ / ₂
32	Bayrick (from Augathella, Q.)	AAH.....	22	11 ¹ / ₂
33	do.....	AH.....	7	10 ¹ / ₂
34	do.....	AE.....	30	10 ¹ / ₂
35	do.....	1 Pcs H.....	20	11
36	do.....	Pcs E.....	23	9 ¹ / ₂
37	AM/Blaigowrie (from Jericho, Q.)	A Pcs E.....	11	8 ¹ / ₂
38	CM/Derribong (from Dandaloo)	A Crs.....	11	3
39	ABT/Wirchilleba (from Cobar)	1 Pcs E.....	11	8
40	ABT/Wirchilleba	2 Pcs E.....	12	5 ¹ / ₂
41	do.....	Locks E.....	6	3 ¹ / ₂
42	HPG/Mugrugulla (from Brewarrina)	AAE.....	13	10 ¹ / ₂
43	do.....	AA XH.....	8	11 ¹ / ₂
No lots 44 to 48.				
SCOURED.				
49	Collearroy.....	1 Pcs.....	9	15 ¹ / ₂
50	Rockview/Collingwood.....	Super F.....	19	22 ³ / ₄
51	do.....	F.....	13	21
52	Bos/Q.....	Locks.....	10	.....
No lots 53 to 65.				
66	RRR.....	M Lks.....	1	9
67	do.....	X-B Locks.....	1	9 ¹ / ₂
68	Collearroy.....	S Pcs.....	2	12 ¹ / ₂
69	Rockview/Collingwood.....	Pcs.....	2	16 ¹ / ₂
70	AM/Blaigowrie.....	Bls.....	4	13 ³ / ₄
71	do.....	Std Pcs.....	2	10 ³ / ₄
72	do.....	Bls and Lks.....	1	9 ¹ / ₂
73	do.....	Locks.....	2	9 ¹ / ₂
74	do.....	Locks.....	1	9
75	ER.....	Pcs.....	1	12 ¹ / ₂
No lots 76 to 199. GREASY.				
200	AB/WIN.....	Pcs.....	2	3
201	do.....	Locks.....	1	1 ³ / ₄
202	H/Nandawar.....	Pcs.....	1	3 ¹ / ₂
203	do.....	Bls.....	1	.....
No lot 204.				
205	WC/Moonan.....	F and Clips.....	1	8
206	EJ/Mt. Vale.....	E.....	1	9 ¹ / ₂
207	HMC/W.....	F.....	1	9
208	CH/Rosehill.....	F.....	5	8 ¹ / ₂
209	do.....	Pcs.....	1	7
210	do.....	Locks.....	1	3 ¹ / ₂
211	WGD/Glendower.....	Lambs.....	1	.....
212	Avery/Alroy.....	CH.....	4	4 ¹ / ₂
213	do.....	FL and CH.....	1	5 ¹ / ₂
214	JK/J/Hollymount.....	W.....	2	11
214a	do.....	E.....	1	10
No lot 215.				
No lot 216.				
217	Springvale/JRH.....	Lambs.....	2	7 ³ / ₄
218	Lumley Park/C.....	X-B Lbs X-B F and MF.....	1	9 ¹ / ₂
219	do.....	X-B Lbs & 2 X-B Lbs.....	1	8 ¹ / ₂
220	JRC/O.....	F.....	2	9 ¹ / ₂
221	do.....	X-B.....	1	8
222	JRRC/O.....	F.....	1	10
223	DC/Highfield.....	EW and H.....	3	11 ¹ / ₂
No lot 224.				
225	Y/Jh/New England.....	Bls and F.....	1	7
226	do.....	Locks and Pcs.....	1	5 ¹ / ₂
227	do.....	F & M & X-B.....	2	10 ³ / ₄
228	do.....	X-B.....	1	9 ¹ / ₂

NOTE.—The prices are given in English pence; 1 penny equals 2 cents.

The sellers made the following comments on some of the lots:

Lot 2. X-bred lambs 21½ cents. Good quality and staple, dry, dusty.

Lot 5. F 23 cents. Fine, good staple and condition, some burr.

Lot 14. Fleece 20½ cents. Fair staple and condition, skirtry.

Lots 18 and 19. 1st Com. 23 cents, A Com. 21½ cents. Fine, soft, good staple, fairly good condition.

Lots 26 to 30. AAAW 26 cents, AAAE 24½ cents, AAE 23½ cents, Pcs. 21½ cents, lambs 23 cents. Fine, soft, well grown, good color and condition.

Lots 32, 34, and 35. AAH 23½ cents, AE 21 cents, 1st Pcs. 22 cents. Good quality and condition, fair staple.

Lot 42. AAE 20½ cents, AAXH 22½ cents. Fine, fair staple, dusty tip.

EXPENSE OF PREPARING WOOL FOR MARKET.

Australian wages for shearing flock wethers, ewes, and lambs are 6 cents per head, with no rations furnished. Wool skirters and rollers, balers, piece pickers and fleece carriers receive \$10.75 per week, without rations. Other shed hands are paid \$8.25 or \$10 per week (without rations), depending upon whether they are under or over 18 years of age. The most common wage for the classer is \$5 per 1,000 sheep shorn. It is considered that 16 men should do the work in a wool room for from 36 to 40 shearers. These are, 1 classer, 6 wool rollers, 4 piece pickers, 1 lock and belly picker, 3 wool pressers, and 1 man to weigh and brand the bales. In addition to this number, boys are needed to sweep the floor and carry fleeces, their number depending largely upon the arrangement of the shed. In one shed visited 12 boys were sweeping and carrying fleeces for 35 shearers, and the total number of employees other than shearers was 38. This shed was not well arranged, the wool was very burry, and the broken fleece wool was passed over the piece pickers' table.

At another New South Wales shearing shed the owner stated that when running with 36 shearers, 24 men and a classer cared for the wool until it was delivered in branded bales. The arrangements in this case reduced the distance for carrying wool but the greatest saving was in the elimination of the piece picking tables and the necessity of gathering skirtings from the floor and carrying them to the tables. The tables were of extra size with four men stationed at each. Each man skirted always from the same part of the fleece and threw the wool into corresponding bins near at hand.

In Australia considerable numbers of sheep are shorn by individuals or companies working on contracts. The sheep owner may or may not furnish the shearing machinery and he may employ his own classer, who then takes charge of the contractor's hands who work in the wool room. In one shed visited, where shearing was done by contract, the owner delivered the sheep at the shed and furnished fuel and quarters for the hands and engaged and paid the classer. The contractor furnished the machinery, sheared the sheep, put up

the wool, and delivered the bales at a charge of 12 cents per sheep, incurring the risk of loss through having to pay wages to shed hands when sheep were too wet for shearing.

SELLING GRADED OR CLASSED WOOLS IN THE UNITED STATES.

The terms "grading" and "classing" have of late come to have distinctive meanings. Grading wool is understood to consist of assigning whole fleeces to different lots according to length and fineness of fiber. Classing is understood to comprise all that grading does, but in addition each fleece is skirted. Fleeces that would go into one grade may, in classing, be made into two or more lots, according to shrinkage, strength, or character. Classing is an elaboration of the principle of grading. It effects a greater uniformity and allows a closer appraisal for each lot of wool. It also entails more labor, and when carried too far, especially with small clips, produces a larger number of small lots than is desirable.

There can be no doubt of the desirability from the wool grower's standpoint of having his wool clip sold in as many separate parts as are necessary to separate the main general classes of wool contained. How far this division, classing, or grading of a clip should be carried depends upon the amount and kinds of wools it contains and upon the selling arrangements.

After many years of classing his clip, the Australian is firmly convinced that he realizes more for his wool by selling it in such number of distinct lots that a manufacturer can find in a single lot just the kind of wool he needs for a particular fabric and can buy that wool alone without having to include in his purchase some wool that he does not want at all or that he can not use for some time.

It seems a reasonable principle that live stock, wool, or any commodity offered in large numbers or amounts will market to better advantage to the seller when broken up into as many distinct lots as the offering includes and each sold on its merits. Good lambs or good wools look and sell much better in a lot by themselves than when mixed with inferior and unattractive stuff. Poor lambs or poor wools look and sell much better by themselves than when mixed with those of higher quality and value.

Aside from added returns from wool and of even greater importance to the grower is the information that such a system furnishes regarding the proportions of each type of wool contained in his clip and the value of each to the manufacturing industry. This allows an accurate determination of the profit from various classes of sheep yielding peculiar types of wool. It may and often does happen that the heavier fleece of wool of slightly lower value per pound yields more profit than a lighter fleece having a higher value per pound. Separate sale of different classes of wool permits the sheep breeder

to determine definitely which class of sheep is most profitable under his conditions.

It is yet too early to say how far and in what way the principles of Australian wool classing and selling can profitably be adopted in the United States. There is nothing in the nature of American sheep or ranch conditions that constitutes an insurmountable obstacle to the employment of even the details of Australian shearing and classing of wool. The great and quite firmly established difference is in the methods of selling. The plan of preparing wool as followed in Australia is possible there because their auction system of selling permits a ready sale of a lot as small as one bale, or 400 pounds of wool. The minimum size of offering that can be satisfactorily disposed of in the American wool trade is 6,000 pounds, and few buyers care to purchase lots of less than 10,000 pounds. This is true because most American wools are purchased by manufacturers' buying representatives in large lines of single grades from dealers who have purchased numerous entire clips at a lump price per pound. Ordinarily each clip contains a considerable amount of each of a number of grades. By combining the few thousand pounds, say, of fine staple wool from one clip with the same kind from one or more other clips, a marketable offering can be made up.

The success of ranch grading of wools is dependent upon the establishing of such selling arrangements as will permit the grower to receive a report showing the weight and selling price of each part of his clip. Under such a method of selling as is used in Australia a mill buyer can secure from any day's offering as large an amount as he needs of any one grade by buying lots of varying amounts of that grade, selected from over a million pounds that may be sold in the auction lasting only a few hours.

Since it is the growers who need and desire a readjustment of American wool-selling methods, it is they who must take the initiative and incur any risks connected with new methods. It is quite plain that the benefits of selling graded wool can not be realized when the clip is sold on the ranch and as a whole. It can not reasonably be expected that speculative buyers, accustomed to buying whole clips, will buy a clip in six or seven parts, neither can the manufacturer in need of, say, 50,000 pounds of a certain class of wool send his buyers to the ranches to bid upon even 10,000 or 15,000 pounds of such wool at a place and then more often than not fail to make a purchase.

The Australian style of auction could not be inaugurated with offerings of classed and catalogued wools equal to less than 20 per cent of the American clip. With 50,000,000 pounds of wool suitably put up and offered by auction for a number of years, that system of doing business might be established. But such a move would neces-

sitate cooperation among growers to an extent not likely to be possible for some years at least.

The only other means of securing the results sought in auction selling is to consign classed or graded clips to commission saleshouses and permit them to combine different parts of various clips such as may be necessary to make up offerings of size suitable to the trade. This is the practice of interlotting described on page 26. Such practice can succeed only when the grower feels that his selling agent, whether it be a cooperative or a private concern, will act fairly and use only wools of similar value in the combined offerings.

Such selling facilities, or any others that are practised, can by no means remove the need of selling houses or firms to get the wool to the manufacturers. Such intermediate agencies may in the future consist more largely than at present of commission sellers, though it is unlikely that the time will ever come when no wool will be bought and held for market rises.

COOPERATIVE SHEARING SHEDS IN NEW ZEALAND.

In New Zealand the sheep raisers are equally as determined as those in Australia to have their wool clips well put up. A few farmers keeping very small flocks do not skirt or class their fleeces, and such clips commonly go to speculators, who do the skirting and classing and in selling combine various purchases so reworked.

Some owners of medium-sized flocks (1,000 to 5,000) cooperate in the ownership and operation of a common shearing plant. Each sheep owner using the shed holds shares of stock in the plant in proportion to the size of his flock. Prior to shearing time the stockholders meet and agree upon a salary for a superintendent selected by them for the season's run. This superintendent hires shearers, shed hands, and a classer, purchases supplies, and in fact does all the business connected with the work, delivering to each stockholder his classed clip in bales, and the season's expense is paid by the stockholders on the basis of the number of sheep shorn for each.

EDUCATION OF WOOL GROWERS AND THEIR EMPLOYEES.

Australia has five agricultural colleges, with a total annual attendance of about 1,000 students. At each college students are given as a part of the agricultural course instruction in the handling of the wool at shearing time, and are required to assist in the work. Other sheep than those owned upon the college farm are sometimes shorn in order to prolong the run and permit each student to take part in each phase of the work. Bales of unskirted or unclassified wools are often purchased to be used as laboratory material in teaching the best methods of preparing a clip of wool for the market.

Agricultural college students also receive instruction upon the breeding and rearing of sheep, though in these lines also most of the time and attention is devoted to practical work. The agricultural college courses are planned equally for prospective farmers and pastoralists.

Apart from the agricultural colleges, instruction pertaining to wools is included among the subjects offered in the technical colleges, schools, and trade schools, of which each State has its own system. New South Wales has 3 technical day schools with two-year courses, and 2 trade schools. In Victoria 20 technical schools receive State aid and 7 of them teach trade subjects. About 40 students were attending classes in wool classing and sorting at the Working Men's College in Melbourne, Victoria, in 1914. The course in wools offered by this college covers two years, students attending 27 hours per week for 40 weeks each year. The work is divided into three grades, outlined as follows:

FIRST GRADE.

To point out any portion of the fleece.

To skirt a fleece properly.

To roll a fleece properly.

To sort skirtings according to their commercial value, making "necks," "broken," "first," "second," and "stained" pieces and "locks," and be able to sort 40 pounds in 30 minutes.

To skirt "bellies" and remove stains where necessary.

To explain what is understood by the terms "combing" and "clothing," and to divide the wool into these two classes.

SECOND GRADE.

To be thoroughly competent in all first-grade work.

To distinguish the following descriptions of wool: Merino, greasy and scoured; comeback, greasy and scoured; quarter-bred, greasy and scoured; half-bred, greasy and scoured; three-quarters bred, greasy and scoured; and Lincoln, greasy and scoured.

To class wool into these qualities.

To be able to sort 28 pounds per hour into these qualities.

To explain the means used in preparing wools for market, as, for instance, "greasy," "scoured," and "fellmongered" wool.

To be able practically to class crossbred fleece and lambs' wool into their respective grades ready for the market, and to class Merino wool, making the distinction between "combing," "clothing," and "tender" wool.

To explain how "crossbred" and "comeback" wools are produced, illustrating by specimens of wool what each crossing will produce.

THIRD GRADE.

To be thoroughly competent in all first and second grade work.

To sort Merino and crossbred wools into all their lengths and qualities.

To sort lambs' wool, either Merino or crossbred, into all its trade qualities.

To sort crossbred and Merino fleeces into trade qualities.

To give an approximate yield of clean wool from greasy.

Certificate will be given only to those passing in the three grades. Before a certificate will be issued, a report from the owner or representative for efficiency in "wool rolling" and "piece picking" during one month's work in a shed of at least 10 shearers must be obtained, and the student must class the wool, supervise piece pickers and wool rollers in a shearing shed to be named for one run (1 hour and 20 minutes) to the satisfaction of two examiners.

New Zealand has day technical schools which include agriculture as one of the studies. Technical work, including such subjects as wool classing, was taught at 132 centers in 1913. At 70 per cent of these centers 1,700 students were taught "wool sorting and classing, shearing, dairying, veterinary service, agriculture, and horticulture." The Christchurch Technical College has a term of three months and requires an attendance of nine hours per week in the course on wool classing. The outline of the course is as follows:

Students are taught how to pick up, roll, skirt, class, and bale wool for the Colonial, London, Continental, and American markets.

Farmers are instructed how to flay and prepare sheep skins and hides for market, both in the dry and green state, and valuation of same at per skin and by weight.

Notes and short lectures are given weekly.

Wool sorting is taught according to Bradford Spinners' Count Qualities, ranging from 32's to 80's.

Second-year students are taught how to estimate the clear yield of wool on a top and noil basis.

The education pertaining to wools offered in Australia and New Zealand is mainly calculated to aid production and train young men for employment with woolgrowers. The only instruction in wools offered in the United States is at a very few textile colleges, which prepare their students to engage in some phase of the manufacture of woollen goods. Although the position of the sheep industry in this country is not relatively so prominent as in Australia, yet its present status and need of development call for educational facilities that do not now exist. There are great areas in the Rocky Mountain and other Western States which in the interests of public welfare and true economy should always be used for sheep raising. While it is beyond the present scope of State institutions to conduct experiments on a scale commensurate with that of ordinary range operations, men and facilities are available for giving instruction that will help to put wool production upon a more skillfully conducted and remunerative basis.

SHEEP RAISERS' ORGANIZATIONS.

Six strong pastoralists' associations in Australia are federated to form a single body, called "The Pastoralists' Federal Council of

Australia." This council consists at present of 12 members, who represent various associations or unions in the States. The purpose of this council is to make orders and regulations to insure unity of action by the federated associations. An important object of all the pastoral associations is to adjust labor matters for their members. They also represent their members in all matters affecting the occupation and development of land for stock farming and grazing purposes.

The relation of local unions or associations to the federal council is shown in the case of the United Pastoralists' and Grazing Farmers' Association of Queensland. This association comprises five district associations, having a total membership of 880 stock owners, representing 63 per cent of the sheep and 28 per cent of the cattle in the State. Each of the district associations holds its own annual meeting.

The executive offices of this State association furnish advice and make representations to the Government land department. During the 1914 meeting discussions were held and action asked or taken on such questions as methods of assessing rates on pastoral holdings, insurance of employees' and members' products, stock stealing, minimum area of grazing farms and homesteads, and extension of leases. During the year members were advised as to action in 19 cases of disputes with shearers and shed hands. Other organizations represented in the federal council have similar functions and subsidiary organizations.

PROBABLE EXTENT OF FUTURE IMPORTATIONS OF MUTTON AND WOOL FROM AUSTRALASIA.

In the minds of many American farmers there exists an uncertainty regarding the influence upon the future course of prices of importations of mutton and wool. Australia and New Zealand are regarded by some as likely to greatly increase their production and supply our markets and thus depress the price of the home-grown products.

These countries can increase their production to a considerable extent. Such an increase can not be a sudden one, and it is doubtful if an additional output can be produced at a lower cost than is possible by the use of the best methods in the United States. None of the land now unoccupied in New Zealand is capable of producing really high-class mutton or wool. An increase of that country's sheep population is to be looked for chiefly through more seeding of natural pastures and the cultivation of forage crops on present natural or artificial grass areas. With the ruling cost of labor and the comparatively slow rate of increase in population, the advance toward any system requiring an increase of labor is likely to be gradual.

In Australia there is a great deal of territory available for new flocks. Much of it, however, is subject to rather frequent droughts,

while labor conditions and restricted construction of railroads render improbable any rapid development. In much of this newer country it requires around 3 acres to support a sheep. Those competent to judge state that the present rate of increase in the sheep population of the interior no more than balances the loss in the moister coastal areas that have supported three sheep per acre and which are now being used more largely for dairying.

Even with favorable seasons and aggressive development in Australia it is improbable that the proportion of the increase reaching the United States would seriously affect our market values. The United States is now one of the small importers of Australasian meats. It may be desirable for shipping companies to divert larger supplies to our ports to furnish eastbound cargo for vessels carrying back American manufactures. With an even greater meat shortage in the other countries receiving Australasian meats than exists here, prices are not likely soon to divert large amounts from European destinations into our markets.

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LOGAN WALLER PAGE, Director

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PROFESSIONAL PAPER.

December 10, 1915

METHODS FOR THE EXAMINATION OF BITUMINOUS ROAD MATERIALS.

By PRÉVOST HUBBARD, *Chemical Engineer*, and
CHARLES S. REEVE, *Chemist*.

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INTRODUCTION.

This bulletin is the first revision of Office of Public Roads Bulletin No. 38, which was issued July 27, 1911. Its object is to present a description of methods now in use by the Office of Public Roads and Rural Engineering for the examination of bituminous road materials in such form that, with a little practice and proper equipment, such examinations may be made by any intelligent person. The various tests have, therefore, been described rather more in detail than would be necessary if they were intended for the use of chemists only; and illustrations of practically all of the apparatus required have also been included.

Since the publication of Bulletin No. 38 considerable progress has been made in the standardization of methods of examining bituminous road materials. Many of the methods described in Bulletin No. 38 have been generally adopted. Certain of these methods have, however, been improved during the past four years and the constant demand for this bulletin has led to its present revision. The changes and additions noted below are the result of investigations conducted in the laboratories of the office and of cooperative work with certain technical societies.

Special attention is called to modifications in the penetration test, determination of fixed carbon, and determination of paraffin scale; and to the substitution of new methods for the old distillation tests and for determination of voids in the mineral aggregate. In addition descriptions of the following methods, which were not included in Bulletin No. 38, are given:

- (1) Determination of flash and burning points—open cup method.
- (2) Dimethyl sulphate test.
- (3) Methods of examining bituminous emulsions.

While it is realized that the following scheme of examination is not perfect and may in the future be improved, it has nevertheless been of great assistance in classifying bituminous road materials and determining their suitability for use according to various methods of application and construction.

CLASSIFICATION OF BITUMINOUS ROAD MATERIALS.

For the purpose of examination bituminous road materials may be classified under the following headings:

1. Petroleums and petroleum products, including heavy distillates, malthas, residual petroleums, fluxes, oil-asphalts, and fluxed or cut-back oil-asphalts.
2. Asphalts and other solid native bitumens, and asphaltic cements produced by fluxing them.
3. Petroleum and asphalt emulsions.
4. Tars and tar products.
5. Mixtures of tar with petroleum or asphalt products.
6. Bituminous aggregates, including rock asphalts or bituminous rocks, bituminous concrete, asphalt block, and bituminous topping.

SCHEME OF EXAMINATION.

All petroleum, maltha, and solid native bitumen products are subjected to the following tests:

- Specific gravity.
- Volatilization at 163° C.
- Bitumen soluble in carbon disulphide.
- Bitumen insoluble in 86° B. paraffin naphtha.
- Fixed carbon.

Of these types the very fluid and sometimes the more viscous products may be subjected to the viscosity, flash, and burning-point determinations. Very viscous materials, too soft for the penetration test, are subjected to the float test, and semisolid and solid products to the penetration test. If the material is sufficiently hard at ordinary temperatures, a melting-point determination may also prove of value. Sometimes two or more of the above-mentioned tests, depending upon the character of the material and the use to which it is to be put, may be made to advantage on a single material. When for any reason it is suspected that the material under examination has been overheated

and possibly injured during process of manufacture, or prepared from a solid native indurated bitumen, the determination of bitumen insoluble in carbon tetrachloride may be made. The paraffin scale determination is made on those materials which are to be identified as being partly composed of heavy paraffin hydrocarbons. The residue obtained from the volatilization test is usually subjected to either the float or penetration test, and in addition it may be subjected to any or all of the above-described tests as occasion may require.

Tar and tar products are subjected to the following tests:

Specific gravity.

Distillation.

Bitumen soluble in carbon disulphide.

Petroleum and asphalt emulsions are subjected to some of the methods of examination applicable to fluid and viscous residual petroleums and also to the following tests:

Determination of water.

Determination of ammonia.

Determination of fixed alkali.

Determination of fatty and resin acids.

In addition, the viscosity test may be employed for fluid products and it is highly desirable that the float test be made on all of the viscous and semisolid tar products. The more or less solid refined tars or tar pitches are also subjected to the melting-point determination. Mixtures of tar and petroleum or asphalt products are in addition subjected to the dimethyl sulphate test.

Some exceptional materials can not be satisfactorily examined according to any one predetermined scheme, and at the present time this matter must be left to the judgment and experience of the analyst. Practically all of the methods described in this bulletin are, however, applicable to the more common materials, and for a given material those methods should be selected which will give the most information concerning its character and suitability for the specific use for which it is intended.

Bituminous aggregates are first of all examined for the percentage of bitumen soluble in carbon disulphide. If the amount is in excess of 5 per cent, an extraction is then made on a large sample and the recovered bitumen is examined according to one of the above-mentioned schemes if it can be identified, or, if not, it is subjected to those tests which are of most value as suggested above. The extracted mineral aggregate is usually quantitatively graded and, if it is to be used or has been used as an integral part of the road proper, its percentage of voids is sometimes determined.

Forms for reporting the results of examination of bituminous road materials according to the methods described in this bulletin are given in the appendix

SPECIFIC GRAVITY DETERMINATION.

HYDROMETER METHOD USED FOR THIN FLUID BITUMENS.

EQUIPMENT.

- 1 hydrometer jar approximately 35 centimeters long and 5 centimeters in diameter. (Fig. 1-a.)
- 1 1-pint tin cup, seamless type. (Fig. 1-b.)
- 1 enamel-ware dish approximately 2 inches deep and 9 inches in diameter. (Fig. 1-c.)
- 1 chemical thermometer reading from -10° C. to 110° C. (Fig. 1-d.)
- 1 set of hydrometers—those with a double scale at 15.5° C. (60° F.), one for Baumé and one for a direct specific gravity reading to the third decimal place are used by the Office of Public Roads and Rural Engineering. (Fig. 1-e.)
- 1 hydrometer reading from 0.800 to 0.900 specific gravity.
- 1 hydrometer reading from 0.900 to 1.000 specific gravity.
- 1 hydrometer reading from 1.000 to 1.200 specific gravity.
- 1 hydrometer reading from 1.200 to 1.400 specific gravity.

METHOD.

The specific gravity of thin fluid bituminous road materials is determined at 25° C. as compared with water at that temperature.

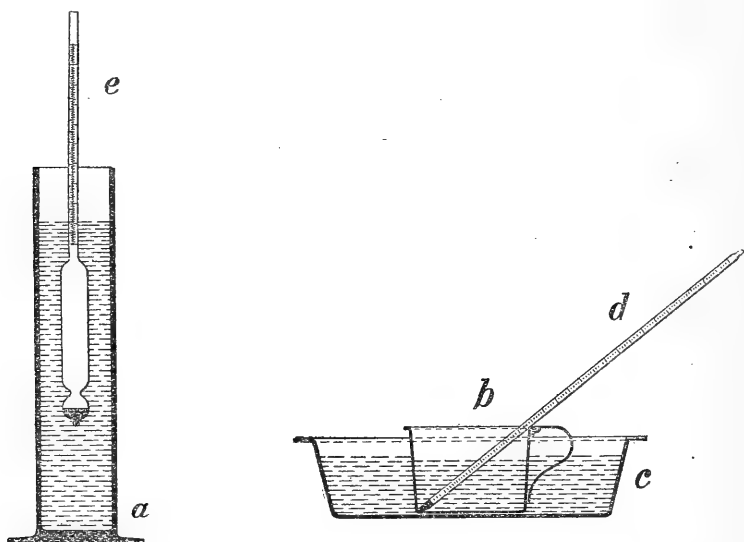


FIG. 1.—Hydrometer method of determining specific gravity.

This may be done with the above-mentioned apparatus by first pouring a sufficient quantity of the material into the tin cup, which is then placed in the large dish containing cold or warm water as occasion may require. The material in the cup should be stirred with the thermometer until it is brought to a temperature of 25° C., after which it should be immediately poured into the hydrometer jar and its gravity determined by means of the proper hydrometer. In case

the hydrometer sinks slowly, owing to the viscosity of the material, it should be given sufficient time to come to a definite resting point, and this point should be checked by raising the hydrometer and allowing it to sink a second time. The hydrometer should never be pushed below the point at which it naturally comes to rest until the last reading has been made. It may then be pushed below the reading for a distance of three or four of the small divisions on the scale, whereupon it should immediately begin to rise. If it fails to do so, the material is too viscous for the hydrometer method, and the pycnometer method should be employed.

The direct specific gravity reading obtained by the foregoing method is based upon water at 15.5° C. taken as unity. For all practical purposes this reading may be corrected to water at 25° C., considered as unity, by multiplying it by 1.002. Thus:

Specific gravity 25° C./25° C. = specific gravity 25° C./15.5° C. $\times$ 1.002

PYCNOMETER METHOD (USED FOR VISCOUS FLUID AND SEMISOLID BITUMENS AND EMULSIONS).

EQUIPMENT.

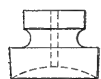
- 1 large metal kitchen spoon.
- 1 steel spatula or kitchen knife.
- 1 Bunsen burner and rubber tubing.
- 1 250 cubic centimeter low-form glass beaker.
- 1 chemical thermometer reading from -10° C. to 110° C.
- 1 special pycnometer. (Fig. 2.)
- 1 analytical balance, capacity 100 grams, sensitive to 0.1 milligram.

METHOD.

The inconvenience and difficulty of employing the ordinary narrow-neck pycnometer when determining the specific gravity of viscous fluid and semisolid bitumens has led to the use of the special form shown in figure 2.

This pycnometer consists of a fairly heavy, straight-walled glass tube, 70 millimeters long and 22 millimeters in diameter, carefully ground to receive an accurately fitting solid glass stopper with a hole of 1.6 millimeters bore in place of the usual capillary opening. The lower part of this stopper is made concave in order to allow all air bubbles to escape through the bore. The depth of the cup-shaped depression is 4.8 millimeters at the center. The stoppered tube has a capacity of about 24 cubic centimeters and when empty weighs about 28 grams. Its principal advantages are (1) that any desired amount of bitumen may be poured in without touching the sides above the level desired; (2) it is easily cleaned; (3) on account of the 1.6-millimeter bore the stopper can be more easily inserted when the tube is filled with a very viscous oil than if it contained a capillary opening.

When working with semisolid bitumens which are too soft to be broken and handled in fragments, the following method of determining their specific gravity is employed. The clean, dry pycnometer is first weighed empty and this weight is called "a." It is then filled in the usual manner with freshly distilled water at 25° C., and the weight is again taken and called "b." A small amount of the bitumen should be placed in the spoon and brought to a fluid condition by the gentle application of heat, with care that no loss by evaporation occurs. When sufficiently fluid, enough is poured into the dry pycnometer, which may also be warmed, to fill it about half full, without allowing the material to touch the sides of the tube above the desired level. The tube and contents are then allowed to cool to room temperature, after which the tube is carefully weighed



with the stopper. This weight is called "c." Distilled water, at 25° C., is then poured in until the pycnometer is full. After this the stopper is inserted, and the whole cooled to 25° C. by a 30-minute immersion in a beaker of distilled water maintained at this temperature. All surplus moisture is then removed with a soft cloth, and the pycnometer and contents are weighed. This weight is called "d." From the weights obtained the specific gravity of the bitumen may be readily calculated by the following formula:

$$\text{Specific gravity } 25^{\circ} \text{ C./} 25^{\circ} \text{ C.} = \frac{c-a}{(b-a) - (d-c)}$$

FIG. 2.—Pycnometer (Hubbard type).

Both "a" and "b" are constants and need be determined but once. It is therefore necessary to make but two weighings for each determination after the first. Results obtained according to the method given above are accurate to within 2 units in the third decimal place, while the open-tube method is accurate to the second decimal place only.

The specific gravity of fluid bitumens may be determined in the ordinary manner with this pycnometer by completely filling it with the material and dividing the weight of the bitumen thus obtained by that of the same volume of water.

The pycnometer may be readily cleaned by placing it in a hot-air bath until the bitumen is sufficiently fluid to pour. As much is drained out as possible and the interior swabbed with a piece of cotton waste. It is then rinsed clean with a little carbon disulphide, and after drying is again ready for use.

DISPLACEMENT METHOD (USED FOR HARD SOLID BITUMENS).

EQUIPMENT.

- 1 chemical thermometer reading from -10° C. to 110° C.
- 1 analytical balance, capacity 100 grams, sensitive to 0.1 milligram.
- 1 wood or metal platform.
- 1 150 cubic centimeter low-form glass beaker.
- 1 piece of fine silk thread.

METHOD.

For materials which are hard enough to be broken and handled in fragments at room temperature, the following method will prove convenient. A small fragment of the bitumen (about 1 cc.) is suspended by means of a silk thread from the hook on one of the pan supports, about $1\frac{1}{2}$ inches above the pan, and weighed. This weight is called "a." It is then weighed immersed in water at 25° C., as shown in figure 3, and this weight is called "b." The specific gravity may then be calculated by means of the following formula:

$$\text{Specific gravity} = \frac{a}{a-b}$$

USE OF SPECIFIC GRAVITY DETERMINATION.

The specific gravity determination is made on all bitumens containing less than 50 per cent mineral matter, and also on bitumens recovered from bituminous aggregates. The specific gravity is usually reported to the third decimal place.

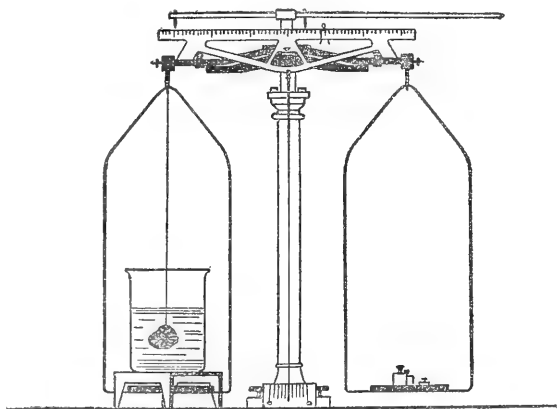


Fig. 3.—Displacement method of determining specific gravity.

SPECIFIC VISCOSITY DETERMINATION.

EQUIPMENT.

- 1 Engler viscosimeter complete with thermometers, burner, and rubber tubing.
- 1 100 cubic centimeter cylindrical glass graduate.
- 1 stop watch.

METHOD.

The viscosity of fluid bituminous road materials may be determined at any suitable temperature by means of the Engler viscosimeter. This apparatus is shown in figure 4, and may be described as follows: *a* is a brass vessel for holding the material to be tested, and may be

closed by the cover *b*. To the conical bottom of *a* is fitted a conical outflow tube *c*, exactly 20 millimeters long, with a diameter at the top of 2.9 millimeters and at the bottom of 2.8 millimeters. This tube can be closed and opened by the pointed hardwood stopper *d*. Pointed metal projections are placed on the inside of *a* at equal distances from the bottom and serve for measuring the charge of material, which is 240 cubic centimeters. The thermometer *e* is used to ascertain the temperature of the material to be tested. The vessel *a* is surrounded by a brass jacket *f*, which holds the material used as a heating bath, either water or cottonseed oil, according to the temperature at which

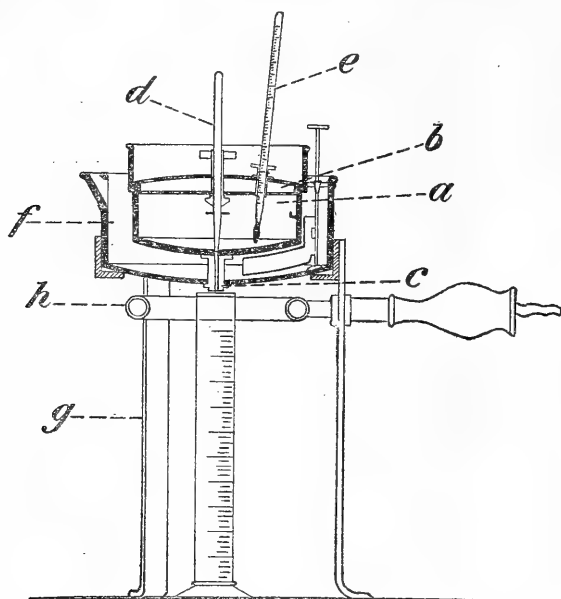


FIG. 4.—Engler viscosimeter.

the test is to be made. A tripod *g* serves as a support for the apparatus and also carries a ring burner *h* by means of which the bath is directly heated. The measuring cylinder of 100 cubic centimeters capacity, which is sufficiently accurate for work with road materials, is placed directly under the outflow tube.

As all viscosity determinations should be compared with

that of water at 25° C., the apparatus should be previously calibrated as follows: The cup and outlet tube should first be scrupulously cleaned. A piece of soft tissue paper is convenient for cleaning the latter. The stopper is then inserted in the tube and the cup filled with water at 25° C. to the top of the projections. The measuring cylinder should be placed directly under the outflow tube so that the material, upon flowing out, will not touch the sides, and the stopper may then be removed. The time required both for 50 and 100 cubic centimeters to run out should be ascertained by means of a stop watch and the results so obtained should be checked a number of times. The time required for 50 cubic centimeters of water should be about 11 seconds and for 100 cubic centimeters about 22.8 seconds.

Bituminous road materials are tested in the same manner as water and the temperature at which the test is made is controlled by the bath. The material should be brought to the desired temperature

and maintained there for at least three minutes before making the test. The results are expressed as specific viscosity compared with water at 25° C., as follows:

$$\text{Specific viscosity at } a^{\circ} \text{ C.} = \frac{\text{seconds for passage of given volume at } a^{\circ} \text{ C.}}{\text{seconds for passage of same volume of water at } 25^{\circ} \text{ C.}}$$

USE OF VISCOSITY DETERMINATION.

For all thin fluid bituminous road materials the specific viscosity is determined at 25° C. with 50 or 100 cubic centimeters. Viscous fluid products are run at 40° C. or 50° C. with 50 cubic centimeters and very viscous products at 100° C. or over with 50 cubic centimeters. This test is not always made on the materials above mentioned, but is a useful one when they are required to have a given degree of fluidity at a given temperature.

FLOAT TEST.

EQUIPMENT.

- 1 aluminum float or saucer. (Fig. 5-a.)
- 2 conical brass collars. (Fig. 5-b.)
- 2 1-quart tin cups, seamless.
- 2 chemical thermometers reading from — 10° C. to 110° C.
- 1 iron tripod.
- 1 Bunsen burner and rubber tubing.
- 1 burette clamp and support.
- 1 large metal kitchen spoon.
- 1 steel spatula or kitchen knife.
- 1 brass plate 5 by 8 centimeters.
- 1 stop watch.

METHOD.

The float apparatus consists of two parts, an aluminum float or saucer (fig. 5-a) and a conical brass collar (fig. 5-b). The two parts are made separately, so that one float may be used with a number of brass collars.

In making the test the brass collar is placed with the small end down on the brass plate, which has been previously amalgamated with mercury by first rubbing it with a dilute solution of mercuric chloride or nitrate and then with mercury. A small quantity of the material to be tested is heated in the metal spoon until quite fluid, with care that it suffers no appreciable loss by volatilization and that it is kept free from air bubbles. It is then poured into the collar in a thin stream until slightly more than level with the top. The surplus may be removed, after the material has cooled to room temperature, by means of a spatula or steel knife which has been slightly heated. The collar and plate are then placed in one of the tin cups containing ice water maintained at 5° C., and left in

this bath for at least 15 minutes. Meanwhile the other cup is filled about three-fourths full of water and placed on the tripod, and the water is heated to any desired temperature at which the test is to be made. This temperature should be accurately maintained, and should at no time throughout the entire test be allowed to vary more than one-half a degree centigrade from the temperature selected. After the material to be tested has been kept in the ice water for at least 15 minutes, the collar with its contents is removed from the plate and screwed into the aluminum float, which is then immediately floated in the warmed bath. As the plug of bituminous material

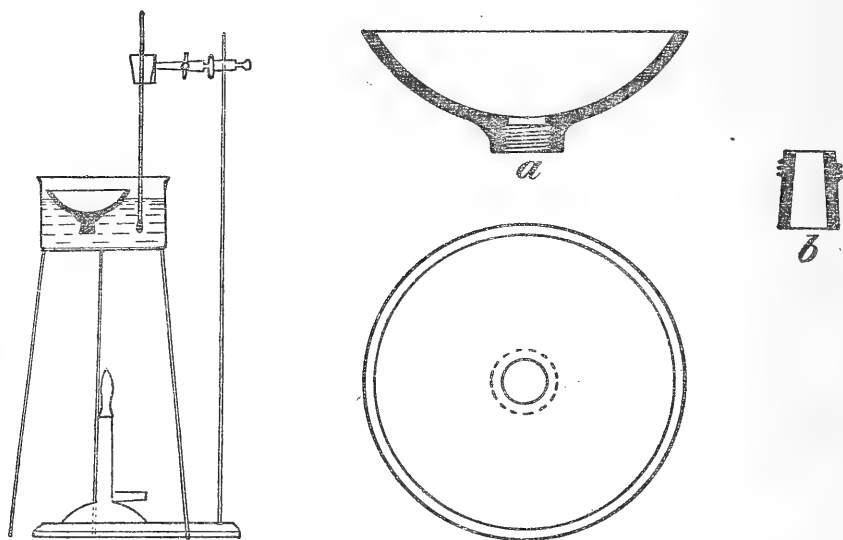


FIG. 5.—New York testing laboratory float apparatus.

becomes warm and fluid, it is gradually forced upward and out of the collar, until water gains entrance to the saucer and causes it to sink.

The time in seconds between placing the apparatus on the water and when the water breaks through the bitumen is determined by means of a stop watch and is taken as a measure of the consistency of the material under examination.

USE OF THE FLOAT TEST.

This test is always made on viscous and semisolid refined tars, and often on the viscous and semisolid petroleum and asphalt products, although, when the penetration test can be employed on the two latter classes of material, the float test is not always considered necessary. For the more fluid products the test is made at 32° C. and for the semisolid materials, at 50° C. When the material under examination is quite hard, the test may be run at 100° C.

The float test is a most convenient one for roughly checking the uniformity of different shipments of bituminous material furnished under specifications.

PENETRATION TEST.

EQUIPMENT.

- 1 penetrometer complete, with a seconds pendulum or metronome. (Figs. 6 and 7.)
- 1 tin box approximately 5 centimeters in diameter by 3.5 centimeters in height.
- 1 large metal kitchen spoon.
- 1 steel spatula or kitchen knife.
- 1 glass penetration dish approximately 10 centimeters in diameter by 6 centimeters high.
- 1 enamel-ware dish approximately 3 inches deep and 9 inches in diameter.
- 1 chemical thermometer reading from -10° C. to 110° C.

METHOD.

The object of the penetration test is to ascertain the consistency of the material under examination by determining the distance a weighted needle will penetrate into it at a given temperature. A standard needle is employed for this purpose and this needle is usually weighted with 100 grams. The depth of penetration is determined upon the bitumen maintained at 25° C., while the load is applied for five seconds.

The standard needle is made from round, polished, annealed-steel drill rod having a diameter of from 0.0405 to 0.0410 inches. The rod is tapered to a sharp point at one end, with the taper extending back one-fourth inch. It is then highly polished, tempered, and again polished with jewelers' rouge. The finished needle is from $1\frac{3}{4}$ to 2 inches in length and exactly 0.040 inch in diameter. This needle, as made in the laboratory of the office, gives the same results as the old standard No. 2 cambric needle, and possesses the advantage that it can be exactly duplicated and accurately described.

The penetration apparatus shown in figure 6 consists of a standard needle *a*, inserted in a short brass rod, which is held in the aluminum rod *b* by a binding screw. The aluminum rod is secured in a framework so weighted and balanced that, when it is supported on the point of the needle, the framework and rod will stand in an upright position, allowing the needle to penetrate perpendicularly without the aid of a support.

The frame, aluminum rod, and needle weigh 100 grams with the weight *c* on the bottom of the frame, while without the weight they weigh 50 grams. Figure 6 shows the needle and weighted frame, together with side and front views of the entire apparatus, put together and ready for making a penetration. The shelf for the sample is marked *d*; *e* is the clamp to hold the aluminum rod until it is desired to make a test; and *f* is a button which, when pressed,

opens the clamp. By turning this button while the clamp is being held open, it will lock and keep the clamp from closing until unlocked. The device for measuring the distance penetrated by the needle consists of a rack, with a foot *g*. The movement of this rack turns a pinion, to which is attached the hand which indicates on the dial *h* the vertical distance covered by the rack. One division of the dial corresponds to a movement of 0.1 millimeter by the rack. The rack may be raised or lowered by moving the counterweight *i* up or down. The tin box containing the sample to be tested is marked *k*; this is submerged in water contained in the glass cup in order to maintain a constant temperature.

This apparatus is known as the Dow penetration machine. Another type of machine known as the New York Testing Laboratory penetrometer, based upon the same general principle and using the same standards, is at present employed by the Office of Public Roads and Rural Engineering. This penetrometer is shown in figure 7. Both machines give practically the same results, if operated under the same conditions, and it is therefore considered unnecessary to include a description of the latter.

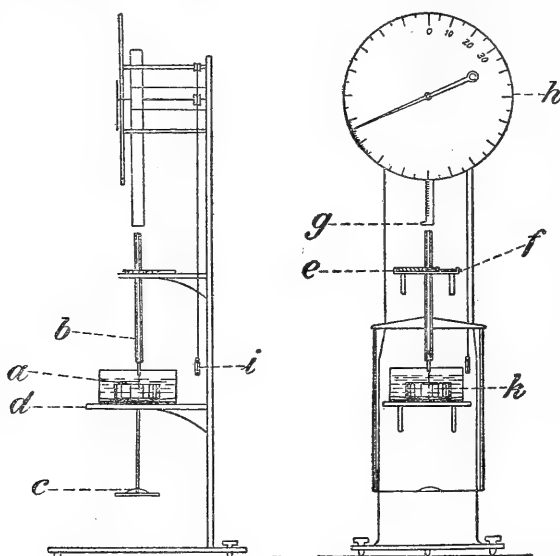


FIG. 6.—Dow penetration machine.

A cup suitable for holding the box containing the test sample during penetration is conveniently made from a glass crystallizing dish 10 centimeters in diameter, with straight sides about 6 centimeters high. Three right triangles with right angle sides 1 and 5 centimeters, respectively, are cut from $\frac{1}{16}$ -inch sheet metal. Some solid bitumen is melted in the bottom of the dish forming a layer about $\frac{1}{8}$ -inch thick, into which the triangles are placed, resting on the side five centimeters long. Their apexes should meet at the center, with their short sides dividing the circumference of the dish into three equal arcs. When the bitumen has hardened, the triangles give a firm support for circular boxes, and the possibility of any rocking motion and consequent faulty results is avoided.

The penetration test is made as follows: A sample of the material to be tested is first warmed sufficiently to flow, and poured into the tin box. The box and contents, after cooling for one-half hour at room temperature, are immersed in water maintained at the temperature at which the test is to be made, and allowed to remain immersed for one and one-half hours. The sample in the tin box should now be placed in the glass cup and removed in it, covered with as much water as convenient without spilling, to the shelf *d*. The brass rod with the needle is inserted into *b* and secured by tightening the binding screw. The rod is lowered until the point of the needle almost touches the surface of the sample; then by grasping the frame with both hands it is cautiously pulled down until the needle just comes in contact with the surface of the sample.

This can be seen best by having a light so situated that, upon looking through the sides of the glass cup, the needle will be reflected from the surface of the sample. After thus setting the needle, the counter-weight is slowly raised until the foot of the rack rests on the head of the rod and a reading of the dial taken. The clamp is then opened wide by press-

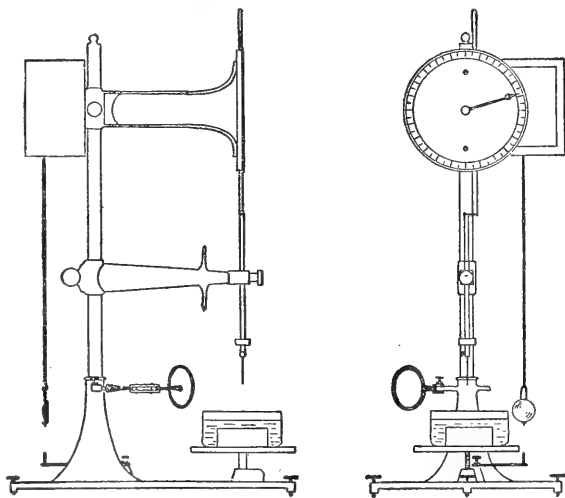


FIG. 7.—New York Testing Laboratory penetrometer.

ing the button and held in this position for exactly five seconds, as determined by the pendulum or metronome. The clamp is then released, the rack lowered until it rests on the rod, and the difference between the first and second readings of the dial in hundredths of a centimeter is taken as the distance penetrated by the needle.

Owing to the susceptibility of certain bitumens to slight changes in temperature, the water-bath should be accurately maintained at the desired temperature, both before and during the test, and, when the room temperature differs greatly from that of the bath, the water in the glass cup should be renewed after each test. An average of from three to five tests, which should not differ more than four points between maximum and minimum, is taken as the penetration of the sample. The tests should be made at points on the surface of the sample not less than one centimeter from the side of the container and not less than one centimeter apart.

The needle should be removed and thoroughly cleaned by wiping with a dry cloth, after which it is ready for another test. The point of the needle should be examined from time to time with a magnifying glass to see that it is not injured in any way. If it is found defective, it may be removed by heating the brass rod and withdrawing with pliers. A new needle may then be inserted in the heated brass rod, and held firmly in place by a drop of soft solder.

USE OF PENETRATION TEST.

This test is made on all semisolid and solid oil-asphalts, asphaltic cements, and native asphalts, but seldom on tar products. It is also often made on the residues of materials subjected to the volatilization tests, when they are sufficiently hard. For work on residues, which seldom amount to more than 20 cubic centimeters, a small container, which should not, however, be less than 1 inch in diameter, will be required.

While the standard conditions under which this test is made call for a 100-gram load applied for five seconds on the material maintained at a temperature of 25° C., it is sometimes desirable, when very soft materials are tested, to make the test with a 50-gram weight. In order to ascertain how susceptible a material may be to temperature changes, tests may be made at any other desired temperatures, preferably 0° C., with a 200-gram weight for one minute, and at 46° C. with a 50-gram weight for five seconds.

In all cases the results of tests should be reported in hundredths of a centimeter, as follows, showing all the conditions in order that no misinterpretation of results may occur:

Penetration (— seconds, — grams at —° C.) = —.

MELTING POINT DETERMINATION.

EQUIPMENT

- 1 iron tripod.
- 1 Bunsen burner and rubber tubing.
- 1 piece of wire gauze 10 centimeters square.
- 1 800 cubic centimeter Jena glass beaker, low form. (Fig. 8-a.)
- 1 400 cubic centimeter Jena glass beaker, tall, without lip. (Fig. 8-b.)
- 1 iron ring support (ring 7.5 centimeters in diameter) and burette clamp. (Fig. 8-c.)
- 1 metal cover. (Fig. 8-d.)
- 1 object glass.
- 1 piece of wire (No. 12 Brown & Sharpe gauge) 20 centimeters in length, bent. (Fig. 8-e.)
- 1 chemical thermometer reading from 0° C. to 250° C.
- 1 cubical brass mold. (Fig. 8-f.)
- 1 large metal kitchen spoon.
- 1 steel spatula or kitchen knife.

METHOD.

Since bitumens are mixtures of various organic compounds, they can have no true melting point, but an arbitrary method for determining the so-called melting point of those materials sufficiently solid to maintain their form for some time under normal conditions is of value as a means of identification and for control work. A number of methods have been tried, but the following has been selected as the most convenient and accurate for such materials.

The material under examination is first melted in the spoon by the gentle application of heat until sufficiently fluid to pour readily. Care must be taken that it suffers no appreciable loss by volatilization. It is then poured into the $\frac{1}{2}$ -inch brass cubical mold, which has been amalgamated with mercury and which is placed on an amalgamated brass plate. The brass may be amalgamated by washing it first with a dilute solution of mercuric chloride or nitrate, after which the mercury is rubbed into the surface. By this means the bitumen is, to a considerable extent, prevented from sticking to the sides of the mold. The hot material should slightly more than fill the mold and, when cooled, the excess may be cut off with a hot spatula.

After cooling to room temperature, the mold is placed in a bath maintained at 25° C. for one-half hour. The cube is then removed and fastened upon the lower arm of a No. 12 wire (Brown & Sharpe gauge), bent at right angles and suspended beside a thermometer in a covered Jena glass beaker of 400 cubic centimeters capacity, which is placed in a water bath, or, for high temperatures, a cottonseed-oil bath. The wire should be passed through the center of two opposite faces of the cube, which is suspended with its base 1 inch above the bottom of the beaker. The water or oil bath consists of an 800-cubic centimeter low-form Jena glass beaker suitably mounted for the application of heat from below. The beaker in which the cube is suspended is of the tall-form Jena type without lip. The metal cover has two openings as shown in figure 8-*d*. A cork, through which

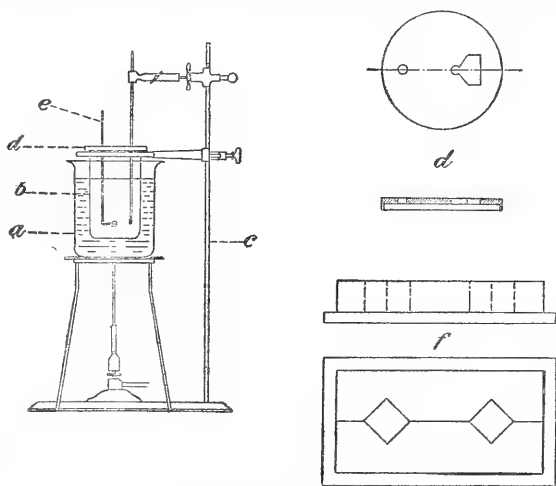


FIG. 8.—Melting point apparatus.

passes the upper arm of the wire, is inserted in one hole and the thermometer in the other. The bulb of the thermometer should be just level with the cube and at an equal distance from the side of the beaker. In order that a reading of the thermometer may be made, if necessary, at the point which passes through the cover, the hole is made triangular in shape and covered with an ordinary object glass through which the stem of the thermometer may be seen. Readings made through this glass should be corrected for the angle of observation, which may be made constant by always sighting from the front edge of the opening to any given point on the stem of the thermometer below the cover.

After the test specimen has been placed in the apparatus, the liquid in the outer vessel is heated in such a manner that the thermometer registers an increase of 5°C . per minute. The temperature at which the bitumen touches a piece of paper placed in the bottom of the beaker is taken as the melting point. Determinations made in the manner described should not vary more than 2° for different tests of the same material. At the beginning of this test the temperature of both bitumen and bath should be approximately 25°C .

USE OF MELTING-POINT DETERMINATION.

The melting-point determination should be made on all bituminous road binders sufficiently hard to be handled at room temperature after removing from the mold. This test is not usually required for bitumens which are to be cut with a nonvolatile flux before use.

DETERMINATION OF FLASH AND BURNING POINTS.

CLOSED-CUP METHOD.

EQUIPMENT.

- 1 New York State Board of Health oil tester with Bunsen burner. (Fig. 9.)
- 1 open-cup oil tester with Bunsen burner. (Fig. 10.)
- 1 chemical thermometer reading from 0°C . to 400°C .
- 1 piece of 6-millimeter glass tubing, 6 centimeters in length, one end of which has been drawn to a 1-millimeter opening. Soft rubber tubing for gas connection.

METHOD.

While for all ordinary purposes the open-cup method of determining the flash and burning points of bituminous road materials is satisfactory, the closed-cup method described below is to be preferred, where greater accuracy is required. This is particularly true for materials of a relatively low flash point.

The oil tester shown in figure 9 consists of a copper oil cup *a* of about 300 cubic centimeters capacity, which is heated in an oil bath *b* by a small Bunsen flame. The cup is provided with a glass cover *c*, carrying a thermometer *d*, and a hole *e* for inserting the

testing flame. The testing flame is obtained from a jet of gas passed through the piece of glass tubing and should be about 5 millimeters in length.

The flash test is made as follows: The oil cup should first be removed and the bath filled with cottonseed oil. The oil cup should be replaced and filled with the material to be tested to within 3 millimeters of the flange joining the cup and the vapor chamber above. The glass cover is then placed on the oil cup and the thermometer so adjusted that its bulb is just covered by the bituminous material. The Bunsen flame should be applied in such a manner that the temperature of the material in the cup is raised at the rate of about 5° C. per minute. From time to time the testing flame is inserted in the opening in the cover to about half way between the surface of the material and the cover. The appearance of a faint bluish flame over the entire surface of the bitumen shows that the flash point has been reached and the temperature at this point is taken.

The burning point of the material may now be obtained by removing the glass cover and replacing the thermometer in a wire frame. The temperature is raised at the same rate and the material tested as before. The temperature at which the material ignites and burns is taken as the burning point.

At the conclusion of this test the flame should not be blown out for danger of splashing the hot material. A metal cover or extinguisher should be employed for this purpose by placing it over the ignited material.

OPEN-CUP METHOD.

A number of open-cup oil testers have been devised which are similar in design and give practically equivalent results. This type is shown in figure 10. It consists of a brass oil cup *a* of about 100 cubic centimeters capacity. The outer vessel *b* serves as an air jacket. No glass cover is used in the open-cup method. A suitable

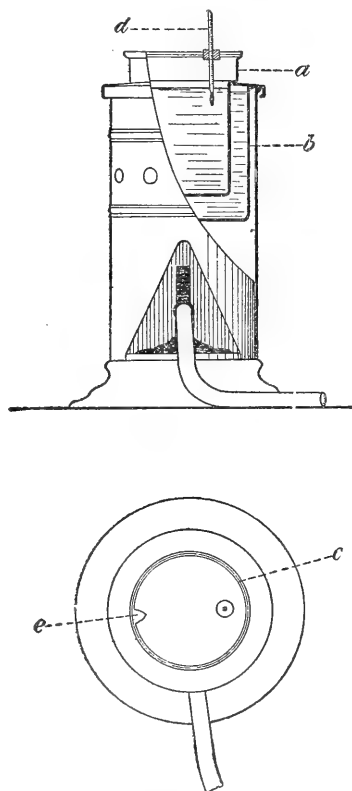


FIG. 9.—New York State Board of Health oil tester.

thermometer *c* is suspended from the wire support *d* directly over the center of the cup so that its bulb is entirely covered with oil but does not touch the bottom of the cup. The testing flame is obtained from a jet of gas passed through a piece of glass tubing, and should be about 5 millimeters in length.

The test is made by first filling the oil cup with the material under examination to within about 5 millimeters of the top. The Bunsen flame is then applied in such a manner that the temperature of the material in the cup is raised at the rate of 5° C. per minute. From time to time the testing flame is brought almost in contact with the surface of the oil. A distinct flicker or flash over the entire surface of the oil shows that the flash point is reached and the temperature at this point is taken. It will usually be found that the flash point as determined by the open-cup method is somewhat higher than by the closed-cup method, for the same material.

The burning point of the material is obtained by continuing the test and noting that temperature at which it ignites and burns. The flame should then be extinguished by means of a metal cover supplied with the instrument.

USE OF FLASH-POINT AND BURNING-POINT DETERMINATIONS.

The flash and burning point determinations should be made on all bituminous road materials which have to be heated before application and upon all fluid and semisolid products

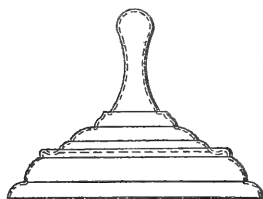
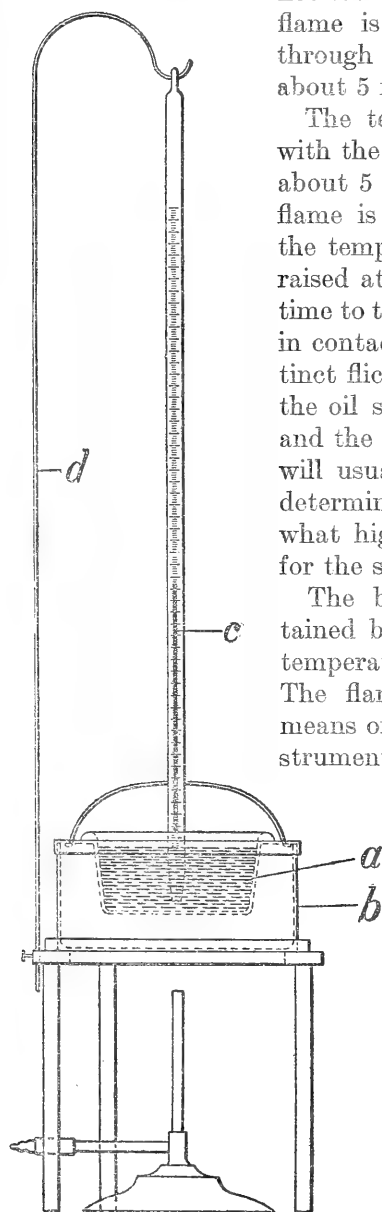


FIG. 10.—Open-cup oil tester.

which show a loss by the volatilization test at 163° C. of over 5 per cent. It should also be made upon fluxes which are to be used in cutting hard bitumens.

VOLATILIZATION TEST.

EQUIPMENT.

- 1 constant-temperature hot-air oven with rubber tubing. (Fig. 11.)
- 1 thermo-regulator. (Fig. 11-a.)
- 2 chemical thermometers reading from -10°C. to 250°C.
- 1 tin box, 6 centimeters in diameter by $\frac{1}{2}$ centimeters deep.
- 1 analytical balance, capacity 100 grams, sensitive to 0.1 milligram.

METHOD.

The object of the volatilization test is to determine the percentage of loss which the material undergoes when 20 grams in a standard-sized container are subjected to a uniform temperature of 163°C. for five hours, and also to ascertain any changes in the character of the material due to such heating.

The oven shown in figure 11, known as the New York Testing Laboratory oven, is used by the Office of Public Roads and Rural Engineering, although any other form may be used that will give a uniform temperature throughout all parts where samples are placed. The bulb of

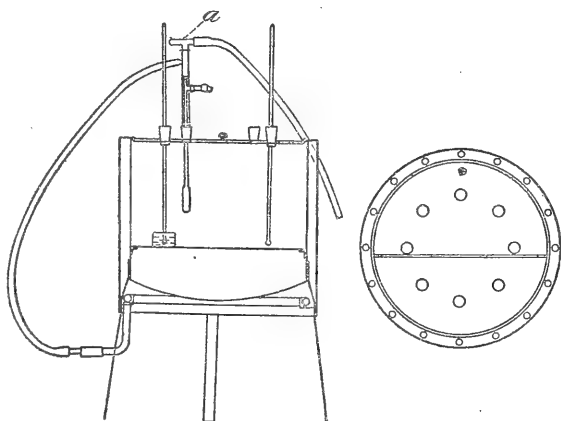


FIG. 11.—New York Testing Laboratory oven.

one of the thermometers is immersed in a sample of some fluid, non-volatile bitumen, while the other is kept in air at the same level. The first thermometer serves to show the temperature of the samples during the test, while the latter gives prompt warning of any sudden changes in temperature due to irregularities in the gas pressure, etc.

Before making the test the interior of the oven should show a temperature of 163°C. as registered by the thermometer in air. The tin box is accurately weighed after carefully wiping with a towel to remove any grease or dirt. About 20 grams of the material to be tested is then placed in the box. The material may then be weighed on a rough balance, if one is at hand, after which the accurate weight, which should not vary more than 0.2 gram from the specified amount, is obtained. It may be necessary to warm some of the material in order to handle it conveniently, after which it must be allowed to cool before determining the accurate weight.

The sample should now be placed in the oven, where it is allowed to remain for a period of five hours, during which time the temperature as shown by the thermometer in bitumen should not vary at any time more than 2° C. from 163° C. The sample is then removed from the oven, allowed to cool, and reweighed. From the difference between this weight and the total weight before heating, the percentage of loss on the amount of material taken is calculated.

The general appearance of the residue should be noted, especially with regard to any changes which the material may have undergone. Some relative idea of the amount of hardening which has taken place may be obtained from the results of a float or penetration test made on the residue, as compared with the results of the same test on the original sample. It is also frequently desirable to make the specific gravity and other tests on the residue for the purpose of identifying or ascertaining the character of the base used in the preparation of cut-back products. Before any tests are made on the residue, it should be melted and thoroughly stirred while cooling.

Highly volatile and nonvolatile materials should not be subjected to this test at the same time in the same oven owing to a tendency on the part of the latter to absorb some of the volatile products of the former.

USE OF THE VOLATILIZATION TEST.

The volatilization test, as above described, is made on practically all bitumens with the exception of tars, for which the distillation test answers a similar purpose. The test is also frequently made at 105° C. for five hours, and with products containing small amounts of water it is usually necessary to make a test at the lower temperature before the material can be heated at 163° C. without foaming over. In the case of emulsions it is customary to determine the loss on a 20-gram sample at room temperature for 24 hours, after which the sample is heated at 105° C. for five hours. This additional loss is obtained and all determinations are made on the dried residue and reported accordingly.

The volatilization test is also occasionally made at 205° C. for five hours on a fresh sample in order to show the effect of this higher temperature as compared with the results at 163° C.

Because of the fact that after the volatilization test it frequently happens that a penetration test can not be made upon the residue of a 20-gram sample in the container specified, it has been suggested that the volatilization test be made upon a 50-gram sample in a tin box $5\frac{1}{2}$ centimeters in diameter and $3\frac{1}{2}$ centimeters in depth. In many cases, however, the percentage loss by volatilization and the consequent hardening will be found to vary materially from that obtained with a 20-gram sample owing to differences in the ratio of exposed surface area to total volume of material. This fact should be borne in mind if the test is made with a 50-gram sample.

DISTILLATION TEST.

EQUIPMENT.

- 1 250 cubic centimeter Engler distillation flask.
- 1 chemical thermometer reading from 0° C. to 400° C.
- 1 short condenser, with rubber tubing.
- 6 25 cubic centimeter glass cylinders, graduated to 0.2 cubic centimeter.
- 1 iron ring support (ring 7.5 cm. in diameter).
- 1 iron tripod.
- 1 burette clamp.
- 1 tin shield.
- 1 pinchcock.
- 2 Bunsen burners, with rubber tubing.
- 1 quart tin cup, seamless.
- 1 pint tin cup, seamless.
- 1 rough balance, capacity 1 kilogram, sensitive to 0.1 gram.
- 1 analytical balance, capacity 100 grams, sensitive to 0.1 milligrams.

METHOD.

The Engler flasks for this test should meet the following requirements:

Diameter of bulb.....	8.0 c. m.
Length of neck.....	15.0 c. m.
Diameter of neck.....	1.7 c. m.
Length of tubulature.....	15.0 c. m.
Diameter of tubulature.....	0.9 c. m.
Angle of tubulature.....	75°

A 3 per cent variation from the above requirements is allowed.

Thermometers should be thoroughly annealed and filled with carbon dioxide or nitrogen under pressure. The mercury column should rise from 15° to 95° in not more than five seconds, when plunged into boiling water.

The thermometers are calibrated by setting up the entire apparatus (fig. 12) as though a distillation of tar were to be made. One hundred cubic centimeters of material of known boiling point is placed in the flask, which is then heated until the contents distil over at a uniform rate and the thermometer indicates a constant temperature, which is noted. By using three different materials of widely varying boiling point, three calibrations on the thermometer scale are obtained from which other intermediate points may be plotted. The correct fractionating points for the calibrated thermometer are then ascertained.

For calibrating thermometers in the laboratories of the Office of Public Roads and Rural Engineering the fractionating points are obtained from the distillation of distilled water (boiling point 100° C.), chemically pure naphthalene (boiling point 218.2° C.), and chemically pure benzophenone (boiling point 305° C.). The boiling point, of course, varies with the barometric pressure, but if the thermometers are calibrated at a time when the barometer indicates about the

average pressure for a given laboratory, the variations in results due to varying pressures when the thermometer is afterwards used for distillation will be no greater than the possible errors in distillation.

The method as a whole is practically the same as that tentatively recommended in 1911 by the Committee on Standard Tests for Road Materials of the American Society for Testing Materials.¹

Briefly described, it consists in distilling 100 cubic centimeters of the refined or dehydrated tar in an Engler flask at a uniform rate of 1 cubic centimeter per minute and collecting the various fractions in weighed glass graduates. In preparing for the test it will be found convenient to mark permanently on the foot of each graduate its weight to within 0.1 gram.

The flask should be supported in a vertical position on one pan of the rough balance and its tare accurately obtained. From the specific gravity of the tar, the weight of 100 cubic centimeters is calculated, and this amount, after warming it in a tin cup, if necessary to make it sufficiently fluid, is poured into the tared flask. A cork stopper carrying the thermometer is then inserted in the neck of the flask,

so that the top of the bulb is opposite the middle of the tubulature, and the entire apparatus set up as shown in figure 12. A tin shield with small sight hole surrounds the flask and burner as shown in order to obviate the influence of drafts.

The tar should be heated gradually by

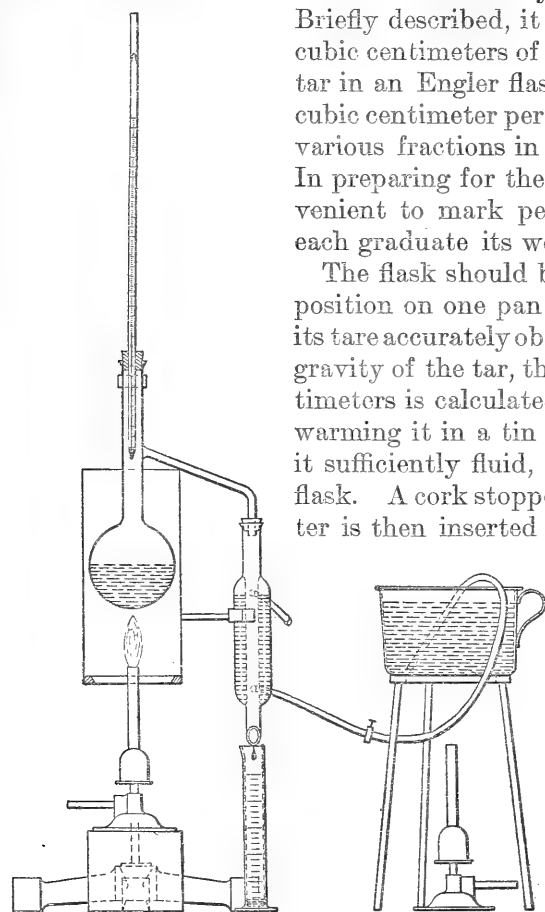


FIG. 12.—Distillation apparatus.

means of a Bunsen burner, and the heat should be so regulated as to maintain distillation at the constant rate of 1 cubic centimeter per minute. When the thermometer registers a temperature corresponding to 110° C., the graduated cylinder containing the first fraction is replaced by another. The receiver is changed again at 170° C. and at 270° C., using as many graduated cylinders as may be necessary without allowing any to become filled above the 25-cubic-centimeter mark.

¹ Proc. Am. Soc. for Testing Materials, 1911, Vol. XI, p. 240.

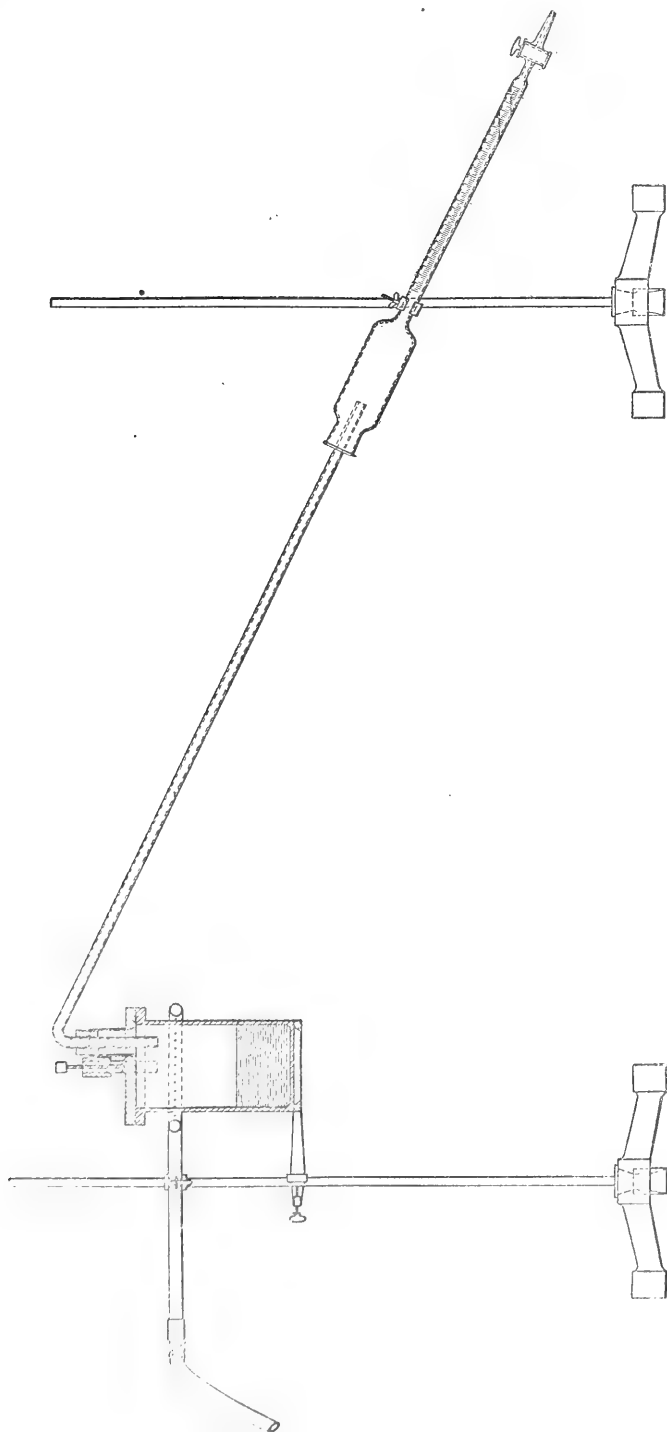


FIG. 13.—Dehydrating apparatus.

When solid matter deposits upon the sides of the condenser, it may be melted by syphoning hot water through the condenser, and collected in the fraction to which it belongs. The last fraction is collected up to 300° C., after which the flask and graduates are cooled to room temperature, and their contents determined by volume and weight. The volume of pitch remaining in the retort is found by deducting the total volume of the distillates from the original 100 cubic centimeters taken. Note should be made of the approximate volume of solids which precipitate from the distillates upon cooling to 25° C.

The results obtained are calculated in percentages by volumes and weights to tenths of 1 per cent and reported as follows:

Distillate.	Per cent, by volume.	Per cent, by weight.
1. Water or ammoniacal liquor.....		
2. First light oils to 110° C.....		
3. Second light oils 110° C. to 170° C.....		
4. Heavy oils 170° C. to 270° C.....		
5. Heavy oils 270° C. to 300° C.....		
6. Pitch residue.....		

The above is applicable only to tars which contain no water. In distilling crude tars or tars which are contaminated with water, it is necessary to dehydrate them before submitting them to the regular distillation. A cylindrical copper still with circular burner, as shown in figure 13, is convenient for this purpose. Two hundred and fifty cubic centimeters of the tar to be dehydrated is weighed in the retort and the apparatus is set up as shown. A low flame is applied to the upper part of the retort and the heating slowly and carefully continued until the volume of water in the separatory funnel shows no further increase. The volume of water collected is noted and calculated. The water is then drained from the separatory funnel and the supernatant layer of oil is run into and thoroughly mixed with the contents of the retort, which should first be cooled below 100° C. A 100 cubic centimeter sample of the dehydrated tar is then submitted to the regular distillation test as above described.

USE OF THE DISTILLATION TEST.

The distillation test is made upon tars and tar products but seldom upon other materials unless the presence of tar is suspected, or where a determination of water is required. In making the water determination on viscous or semisolid bituminous materials, it is usually advisable to render the samples fluid by the addition of kerosene or benzol before attempting the distillation.

DIMETHYL SULPHATE TEST.**EQUIPMENT.**

Same as specified under distillation test, and in addition: 3 10-cubic centimeter glass cylinders with ground-glass stoppers, graduated to 0.2 cubic centimeter.

METHOD.

The dimethyl sulphate test is employed to detect the presence of petroleum or asphalt products in tar. The pitch (above 300° C.) obtained from the distillation test is used. This pitch, after being cooled and weighed, is again distilled. Fractions are taken at 350° C. and 375° C. These fractions, together with the 270–300° C. fraction previously obtained, are separately stirred and, if necessary, heated to dissolve solids which may be present.

Four cubic centimeters of distillate from each fraction are separately shaken with 6 cubic centimeters of dimethyl sulphate in a 10-cubic centimeter cylinder. After standing 30 minutes the resulting supernatant layer of insoluble oil, from the petroleum or asphalt, is read and calculated to its percentage by volume of the sample of distillate taken. The results are reported as follows:

Fractions.	Per cent of distillate.	Per cent of distillate insoluble in dimethyl sulphate.
270° to 306° C.		
300° to 350° C.		
350° to 375° C.		

USE OF DIMETHYL SULPHATE TEST.

The dimethyl sulphate test is used only in cases where a mixture of petroleum or asphalt products with tar has been specified or is suspected. The test is mainly qualitative, but is valuable when as little as 3 per cent of petroleum or asphalt products are present in the tar.

DETERMINATION OF BITUMEN SOLUBLE IN CARBON DISULPHIDE.**EQUIPMENT.**

- 1 100 cubic centimeter Erlenmeyer flask.
- 1 500 cubic centimeter flask with side neck for filtering under pressure.
- 1 rubber stopper with one hole.
- 1 filter tube, 3.9 centimeters, inside diameter.
- 1 platinum or porcelain Gooch crucible.
- 1 piece of seamless rubber tubing, about 3 centimeters in diameter and 3 centimeters long.
- 50 grams of long-fiber amphibole asbestos.

- 2 wash bottles; 1 for solvent, 1 for water.
- 1 Bunsen burner.
- 1 nichrome triangle.
- 1 iron tripod.
- 1 drying oven.
- 1 desiccator with calcium chloride.
- 1 thermometer reading from -10° C. to 110° C.
- 1 vacuum pump and connections.
- 1 analytical balance, capacity 100 grams, sensitive to 0.1 milligram.

METHOD.

This test consists in dissolving the bitumen in carbon disulphide and recovering any insoluble matter by filtering the solution through an asbestos felt. The form of Gooch crucible best adapted for the determination is 4.4 centimeters wide at the top, tapering to 3.6 centimeters at the bottom, and is 2.5 centimeters deep.

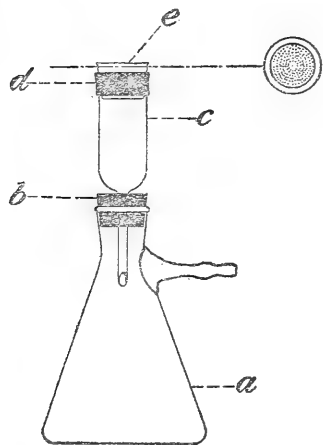


FIG. 14.—Apparatus for determining soluble bitumen.

For preparing the felt the necessary apparatus is arranged as shown in figure 14, in which *a* is the filtering flask, *b* a rubber stopper, *c* the filter tube, and *d* a section of rubber tubing which tightly clasps the Gooch crucible *e*. The asbestos is cut with scissors into pieces not exceeding 1 centimeter in length, after which it is shaken up with just sufficient water to pour easily. The crucible is filled with the suspended asbestos, which is allowed to settle for a few moments. A light suction is then applied to draw off all the water and leave a firm mat of asbestos in the crucible.

More of the suspended material is added, and the operation is repeated until the felt is so dense that it scarcely transmits light when held so that the bottom of the crucible is between the eye and the source of light. The felt should then be washed several times with water, and drawn firmly against the bottom of the crucible by an increased suction. The crucible is removed to a drying oven for a few minutes, after which it is ignited at red heat over a Bunsen burner, cooled in a desiccator and weighed.

From 1 to 2 grams of bitumen or about 10 grams of an asphalt topping or rock asphalt is now placed in the Erlenmeyer flask, which has been previously weighed, and the accurate weight of the sample is obtained. One hundred cubic centimeters of chemically pure carbon disulphide is poured into the flask in small portions, with continual agitation, until all lumps disappear and nothing adheres to the bottom. The flask is then corked and set aside for 15 minutes.

After being weighed, the Gooch crucible containing the felt is set up over the dry pressure flask, as shown in figure 14, and the solution of bitumen in carbon disulphide is decanted through the felt without suction by gradually tilting the flask, with care not to stir up any precipitate that may have settled out. At the first sign of any sediment coming out, the decantation is stopped and the filter allowed to drain. A small amount of carbon disulphide is then washed down the sides of the flask, after which the precipitate is brought upon the felt and the flask scrubbed, if necessary, with a feather or "policeman," to remove all adhering material. The contents of the crucible are washed with carbon disulphide, until the washings run colorless. Suction is then applied until there is practically no odor of carbon disulphide in the crucible, after which the outside of the crucible is cleaned with a cloth moistened with a small amount of the solvent. The crucible and contents are dried in the hot-air oven at 100°C . for about 20 minutes, cooled in a desiccator, and weighed. If any appreciable amount of insoluble matter adheres to the flask, it should also be dried and weighed, and any increase over the original weight of the flask should be added to the weight of insoluble matter in the crucible. The total weight of insoluble material may include both organic and mineral matter. The former, if present, is burned off by ignition at a red heat until no incandescent particles remain, thus leaving the mineral matter or ash, which can be weighed on cooling. The difference between the total weight of material insoluble in carbon disulphide and the weight of substance taken equals the total bitumen, and the percentage weights are calculated and reported as total bitumen, and organic and inorganic matter insoluble, on the basis of the weight of material taken for analysis.

This method is quite satisfactory for straight oil and tar products, but where certain natural asphalts are present it will be found practically impossible to retain all of the finely divided mineral matter on an asbestos felt. It is, therefore, generally more accurate to obtain the result for total mineral matter by direct ignition of a 1-gram sample in a platinum crucible or to use the result for ash obtained in the fixed carbon test. The total bitumen is then determined by deducting from 100 per cent the sum of the percentages of total mineral matter and organic matter insoluble. If the presence of a carbonate mineral is suspected, the percentage of mineral matter may be most accurately obtained by treating the ash from the fixed carbon determination with a few drops of ammonium carbonate solution, drying at 100°C ., then heating for a few minutes at a dull red heat, cooling, and weighing again.

When difficulty in filtering is experienced—for instance, when Trinidad asphalt is present in any amount—a period of longer subsidence

than 15 minutes is necessary, and the following method proposed by the Committee on Standard Tests for Road Materials of the American Society for Testing Materials is recommended: ¹

From 2 to 15 grams (depending on the richness in bitumen of the substance) is weighed into a 150-cubic centimeter Erlenmeyer flask, the tare of which has been previously ascertained, and treated with 100 cubic centimeters of carbon disulphide. The flask is then loosely corked and shaken from time to time until practically all large particles of the material have been broken up, when it is set aside and not disturbed for 48 hours. The solution is then decanted off into a similar flask that has been previously weighed, as much of the solvent being poured off as possible without disturbing the residue. The first flask is again treated with fresh carbon disulphide and shaken as before, when it is put away with the second flask and not disturbed for 48 hours.

At the end of this time the contents of the two flasks are carefully decanted off upon a weighed Gooch crucible fitted with an asbestos filter, the contents of the second flask being passed through the filter first. The asbestos filter shall be made of ignited long-fiber amphibole, packed in the bottom of a Gooch crucible to the depth of not over one-eighth of an inch. After passing the contents of both flasks through the filter, the two residues are shaken with more fresh carbon disulphide and set aside for 24 hours without disturbing, or until it is seen that a good subsidence has taken place, when the solvent is again decanted off upon the filter. This washing is continued until the filtrate or washings are practically colorless.

The crucible and both flasks are then dried at 125° C. and weighed. The filtrate containing the bitumen is evaporated, the bituminous residue burned, and the weight of the ash thus obtained added to that of the residue in the two flasks and the crucible. The sum of these weights deducted from the weight of substance taken gives the weight of bitumen extracted.

USE OF TOTAL BITUMEN DETERMINATION.

This determination is made on all classes of bituminous products. In the analysis of tars the organic matter insoluble is commonly known and reported as "free carbon."

DETERMINATION OF BITUMEN INSOLUBLE IN PARAFFIN NAPHTHA.

EQUIPMENT.

The apparatus is the same as for bitumen soluble in carbon disulphide.

METHOD.

This determination is made in the same general manner as the total bitumen determination, except that 100 cubic centimeters of 86° to 88° B. paraffin naphtha, at least 85 per cent distilling between 35° C. and 65° C., is employed as a solvent instead of carbon disulphide. Considerable difficulty is sometimes experienced in breaking up some of the heavy semisolid bitumens; the surface of the material is attacked, but it is necessary to remove some of the insoluble matter in order to expose fresh material to the action of the solvent. It is, therefore, advisable to heat the sample after it is weighed, allowing it to cool in a thin layer around the lower part of

¹ Proc. Am. Soc. for Testing Materials, 1909, Vol. IX, p. 221.

the flask. If difficulty is still experienced in dissolving the material, a rounded glass rod will be found convenient for breaking up the undissolved particles. Not more than one-half of the total amount of naphtha required should be used until the sample is entirely broken up. The balance of the 100 cubic centimeters is then added, and the flask is twirled a moment in order to mix the contents thoroughly, after which it is corked and set aside for 30 minutes.

In making the filtration the utmost care should be exercised to avoid stirring up any of the precipitate, in order that the filter may not be clogged and that the first decantation may be as complete as possible. The sides of the flask should then be quickly washed down with naphtha and, when the crucible has drained, the bulk of insoluble matter is brought upon the felt. Suction may be applied when the filtration by gravity almost ceases, but should be used sparingly, as it tends to clog the filter by packing the precipitate too tightly. The material on the felt should never be allowed to run entirely dry until the washing is completed, as shown by the colorless filtrate. When considerable insoluble matter adheres to the flask no attempt should be made to remove it completely. In such cases the adhering material is merely washed until free from soluble matter, and the flask is dried with the crucible at 100° C. for about one hour, after which it is cooled and weighed. The percentage of bitumen insoluble is reported upon the basis of total bitumen taken as 100.

The difference between the material insoluble in carbon disulphide and in the naphtha is the bitumen insoluble in the latter. Thus, if in a certain instance it is found that the material insoluble in carbon disulphide amounts to 1 per cent and that 10.9 per cent is insoluble in naphtha, the percentage of bitumen insoluble would be calculated as follows:

$$\frac{\text{Bitumen insoluble in naphtha}}{\text{Total bitumen}} = \frac{10.9 - 1}{100 - 1} = \frac{9.9}{99} = 10 \text{ per cent}$$

USE OF NAPHTHA INSOLUBLE BITUMEN DETERMINATION.

This test is made on all petroleum, malthas, asphalts, and other solid native bitumens and their products.

It should be noted that petroleum naphthas are by no means definite compounds, but are composed of a number of hydrocarbons which vary in character and quantity according to the petroleum from which they have been distilled. Their solvent powers also vary greatly. Thus naphthas produced from asphaltic petroleum, consisting mainly of naphthene and polymethylene hydrocarbons, are much more powerful solvents of the heavier asphaltic hydrocarbons than are the paraffin naphthas. The density of the naphtha also affects its solvent power, for those of high specific gravity dissolve the

heavier hydrocarbons more readily than those of lower specific gravity. As the main object of this test is to separate the heavier hydrocarbons of an asphaltic nature from the paraffin hydrocarbons, a paraffin solvent should be employed, and for ordinary purposes a paraffin naphtha of 86° to 88° B. as described has been found to be readily obtainable and fairly satisfactory.

The determination is also frequently made with heavier naphthas, such as 66° B. and 72° B., for the purpose of grading the character of the bitumen present in the compound. A report should therefore always distinctly state the gravity and character of the solvent used.

DETERMINATION OF BITUMEN INSOLUBLE IN CARBON TETRACHLORIDE.

EQUIPMENT.

The apparatus is the same as for bitumen soluble in carbon disulphide.

METHOD.

This determination is conducted in exactly the same manner as described under "Determination of bitumen soluble in carbon disulphide," using 100 cubic centimeters of chemically pure carbon tetrachloride in place of carbon disulphide.

The percentage of bitumen insoluble is reported upon the basis of total bitumen taken as 100, as described under "Determination of bitumen insoluble in paraffin naphtha."

USE OF DETERMINATION OF BITUMEN INSOLUBLE IN CARBON TETRACHLORIDE.

The bitumen insoluble in carbon tetrachloride, but soluble in carbon disulphide, is commonly known as "carbenes." The test is occasionally made on petroleum, asphalts, and other solid native bitumens and their products, for the purpose of identification, or when there is any reason to suspect that the material under examination has been injured by overheating during the process of manufacture.

DETERMINATION OF FIXED CARBON.

EQUIPMENT.

- 1 iron ring support (ring 7.5 cm. in diameter).
- 1 platinum or nichrome triangle.
- 1 Bunsen burner and rubber tubing.
- 1 platinum crucible with a tight-fitting cover (weight complete, from 20 to 30 grams).
- 1 crucible tongs.
- 1 desiccator with calcium chloride.
- 1 analytical balance, capacity 100 grams, sensitive to 0.1 milligram.

METHOD.

This determination is made in accordance with the method described for coal in the Journal of the American Chemical Society,

1899, volume 21, page 1116. One gram of the material is placed in a platinum crucible weighing from 20 to 30 grams and having a tightly fitting cover. It is then heated for seven minutes over the full flame of a Bunsen burner, as shown in figure 15. The crucible should be supported on a platinum triangle with the bottom from 6 to 8 centimeters above the top of the burner. The flame should be fully 20 centimeters high when burning freely, and the determination should be made in a place free from drafts. The upper surface of the cover should burn clear, but the under surface should remain covered with carbon, excepting in the case of some of the more fluid bitumens, when the under surface of the cover may be quite clean.

The crucible is removed to a desiccator and when cool is weighed, after which the cover is removed, and the crucible is placed in an inclined position over the Bunsen burner and ignited until nothing but ash remains. Any carbon deposited on the cover is also burned off. The weight of ash remaining is deducted from the weight of the residue after the first ignition of the sample. This gives the weight of the so-called fixed or residual carbon, which is calculated on a basis of the total weight of the sample, exclusive of mineral matter. If the presence of a carbonate mineral is suspected, the percentage of mineral matter may be most accurately obtained by treating the ash with a few drops of ammonium carbonate solution, drying at 100° C., then heating for a few minutes at a dull red heat, cooling and weighing.

An excellent form of crucible for this test is shown in figure 15. It has a cover with a flange 4 millimeters wide, fitting tightly over the outside of the crucible, and weighs complete about 25 grams. Owing to sudden expansion in burning some of the more fluid bitumens, it is well to hold the cover down with the end of the tongs until the most volatile products have burned off.

Some products, particularly those derived from Mexican petroleum, show a tendency to suddenly expand and foam over the sides of the crucible in making this determination, and no method of obviating this trouble without vitiating the result has thus far been forthcoming. Recent experiments in the laboratory of the Office of

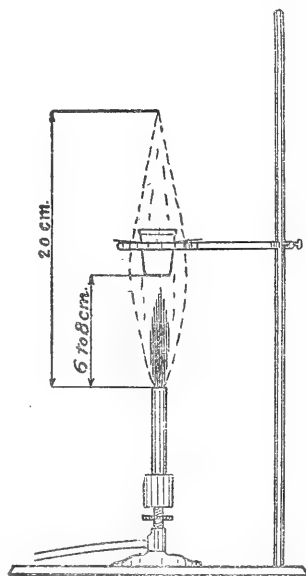


FIG. 15.—Apparatus for determining fixed carbon.

Public Roads and Rural Engineering indicate that the difficulty may be overcome by placing a small piece of platinum gauze over the sample and about midway of the crucible. The gauze should be so cut or bent as to touch the sides of the crucible at all points, and is of course weighed in place in the crucible before and after ignition.

USE OF DETERMINATION FOR FIXED CARBON.

This determination is made on all bituminous products with the exception of tars, upon which reliable results can not be obtained, owing to the error introduced by the presence of considerable quantities of free carbon.

DETERMINATION OF PARAFFIN SCALE.

EQUIPMENT.

- 1 one-half pint iron retort. (Fig. 16.)
- 1 piece iron tubing, 30 inches long.
- 2 100 cubic centimeter Erlenmeyer flasks.
- 1 500 cubic centimeter (16 oz.) flask, with side neck for filtering under pressure.
- 1 freezing apparatus. (Fig. 17.)
- 1 6-inch test tube, $\frac{3}{8}$ -inch diameter.
- 1 analytical balance, capacity 100 grams, sensitive to 0.1 milligram.
- 1 rough balance, capacity 1 kilogram, sensitive to 0.1 gram.
- 1 wash bottle.
- 1 pint tin cup, seamless.
- 1 vacuum pump and connections.
- 1 glass crystallizing dish, 50 millimeters in diameter.
- 1 steam bath.
- 1 desiccator with calcium chloride.
- 1 4-inch steel spatula.
- 1 Bunsen burner with rubber tubing.
- 2 iron stands with retort clamp, and 1 ring.

METHOD.

Fifty grams of the material under examination should be weighed into the tared iron retort and distilled as rapidly as possible to dry coke. The distillation should be complete in not over 25 minutes. The distillate is caught in a 100-cubic centimeter Erlenmeyer flask, the weight of which has been previously ascertained. During the early stages of distillation a cold, damp towel wrapped around the stem of the retort will serve to condense the distillate. After high temperatures have been reached, this towel may be removed. When the distillation is completed the distillate is allowed to cool to room temperature and is then weighed in the flask. This weight minus that of the flask gives the weight of the total distillate.

The apparatus for freezing out and separating the paraffin scale is shown in figure 17. It consists of a bell jar *a* about 16 centimeters high and 14 centimeters in diameter, surrounded by a felt or cotton

cover *b*. A copper jacket *c*, $4\frac{1}{2}$ centimeters in diameter at the top and 21 centimeters long, is held in the neck of the bell jar by means of a rubber stopper *d*, and fits into the upper portion of the rubber stopper *j*. A glass filter tube *e* fits inside the copper jacket, and to prevent circulation of air and condensation of water between it and the jacket, a strip of heavy blotting paper *f* is wrapped around the top of the filter tube. Just below the constriction in the filter tube a wad of absorbent cotton *g* is placed, tightly compressed to a length of 2 centimeters by means of a glass rod. Above this is a wad of tightly packed asbestos wool *h*, about 5 millimeters in length, upon which an asbestos filtering mat *i* is prepared. The filter tube passes through a rubber stopper *j* into a vacuum filtering flask *k* of 500 cubic centimeters capacity. The rubber stopper *j* is placed as tightly as possible against the neck of the bell jar, but to insure that there is no circulation of air, a disk of blotting paper *l* is compressed between them. The thermometer *m* is capable of recording temperatures from -25°C . to 0°C . and has the

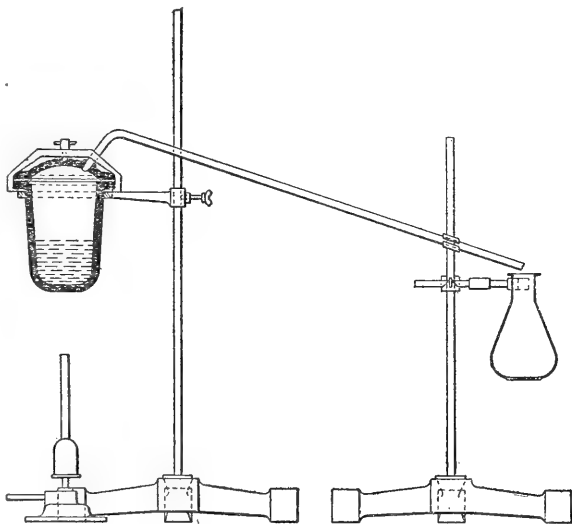


FIG. 16.—Apparatus for distillation in determination of paraffin scale.

-20°C . graduation at least 14 centimeters from the bulb. It is supported by means of a guiding cork *n* and cork disk *o*, which is held tightly against the top of the filter tube by the clamp *p*.

The bell jar is filled with a freezing mixture of ice and salt in the proportion of three to one, which as it melts is drawn off through the bent glass tube *g*, which is fitted with a rubber connection *r* and pinchcock *s* and collected in the 500 cubic centimeter filtering flask *t*. The apparatus is supported on the ring *u* and condenser clamp *v*, attached to the stand *w*.

In separating the paraffin scale the following procedure is carried out. The filtering flask *k* is removed and a small cork stopper inserted in the lower end of the filter tube to assist in retaining the solution to be chilled in the upper part of the tube. Ten cubic centimeters of a mixture of equal parts Squibbs' ether and absolute alcohol

is poured into the filter tube, the temperature of which has been reduced to -20°C . From one to two grams of the well-mixed distillate obtained in the manner previously described is then accurately weighed in a 100 cubic centimeter Erlenmeyer flask, mixed with 10 cubic centimeters of Squibbs' ether, and poured into the filter tube. Ten cubic centimeters of absolute alcohol is next placed in the flask to wash out the ether solution, poured into the filter tube, and the

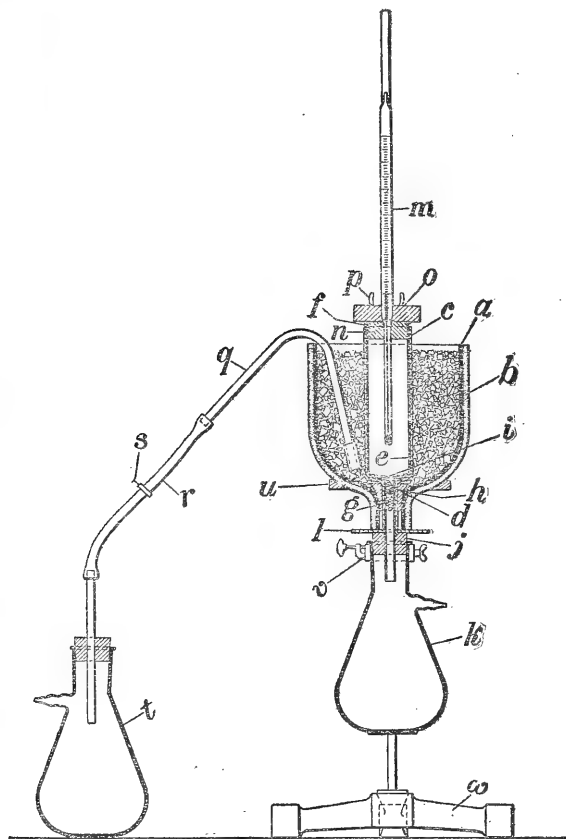


FIG. 17.—Freezing apparatus for determining paraffin scale.

cover carrying the thermometer placed on the tube. The mixture is maintained at a temperature of -20°C . for 15 minutes, then the cork stopper is removed from the outlet of the filter tube and the filtering flask is replaced. The corks supporting the thermometer are now loosened and a strong suction is applied to the filter flask until all of the solvent is drawn off. The contents of the filter tube are next washed with 10 cubic centimeters of a 1 to 1 mixture of Squibbs' ether and absolute alcohol, which is chilled to -20°C . in the filter tube before suction is applied.

When the washings have been removed the vacuum is turned off and the filter tube removed from the apparatus. The filter tube is then placed in a clean filter flask which also contains a 6-inch test tube in which the dissolved paraffin scale is later collected. About 10 cubic centimeters of warm petroleum ether is poured into the filter tube and allowed to remain until the paraffin scale has been dissolved. Vacuum is then applied and the dissolved scale drawn into the test tube. This treatment is followed by two washings, one of 10 cubic centimeters and the other of 5 cubic centimeters of warm petroleum ether, which removes the last traces of paraffin scale. The entire contents of the test tube are

then poured into a weighed platinum or glass crystallizing dish and the petroleum ether evaporated off over a steam bath. The dish is then placed in a drying oven maintained at 105° C. until the last traces of petroleum ether have been removed and the paraffin scale has attained a constant weight, after cooling in a desiccator.

The weight of the paraffin scale so obtained, divided by the weight of the distillate taken and multiplied by the percentage of the total distillate obtained from the original sample, equals the percentage of the paraffin scale.

USE OF PARAFFIN SCALE DETERMINATION.

The paraffin scale determination may be made on all native bitumens and their products which are suspected of being of a paraffin nature. It is not an extremely accurate determination, however, and is seldom employed by the Office of Public Roads and Rural Engineering.

THE EXTRACTION OF BITUMINOUS AGGREGATES.

EQUIPMENT FOR RECOVERING AGGREGATE ONLY.

- 1 centrifuge extractor, complete with motor, speed regulator, and electrical connections. (Fig. 18.)
- 1 hot plate.
- 1 enamel-ware dish approximately 2 inches deep and 9 inches in diameter.
- 1 hammer.
- 1 three-fourths-inch cold chisel.
- 1 large metal kitchen spoon.
- 1 square foot of one-sixteenth-inch deadening felt paper.
- 1 1½-inch stiff flat brush.
- 1 500-cubic-centimeter bottle or flask.
- 1 balance, capacity 1 kilogram, sensitive to 0.1 gram.
- 1 sheet of heavy manila paper.

ADDITIONAL EQUIPMENT FOR RECOVERING BITUMEN.

- 1 iron ring support (ring 10 centimeters in diameter).
- 1 iron ring support with condenser clamp.
- 1 round tin can, 10 by 12 centimeters, covered with asbestos paper.
- 1 100-watt incandescent carbon-filament lamp, with socket and connections.
- 1 asbestos hood. (Fig. 19-c.)
- 1 1,000-cubic-centimeter round-bottom flask, with cork.
- 1 spiral condenser, length of body 25 centimeters, with cork to fit, and rubber-tubing connections.
- 50 centimeters of glass tubing, 8 millimeters bore.
- 1 1,000-cubic-centimeter flat-bottom flask.
- 1 porcelain evaporating dish, 11 centimeters in diameter.
- 1 watch glass, 20 centimeters in diameter.
- 1 steam bath.

METHOD.

The extractor shown in figure 18 was designed upon lines suggested by an examination of machines in use by A. E. Schutte and C. N. Forrest. It consists of a one-fifth-horsepower 1,100 revolutions per minute vertical-shaft electric motor *a*, with the shaft projecting into the cylindrical copper box *b*, the bottom of which is so inclined as to drain to the spout *c*. A three-sixteenths-inch circular brass plate $9\frac{1}{2}$ inches in diameter is shown in *d*, and upon this rests the sheet-iron bowl *e*, which is $8\frac{1}{2}$ inches in diameter by $2\frac{5}{16}$ inches high, and has a 2-inch circular hole in the top. Fastened to the inner side of the bowl is

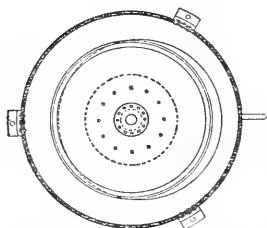
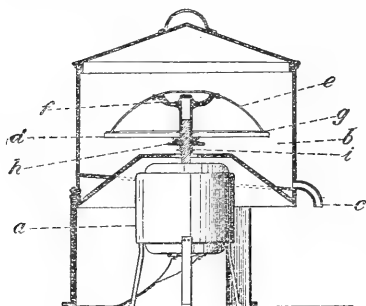


FIG. 18.—Centrifuge extractor
(Reeve type).

the brass cup *f*, having a circle of one-eighth-inch holes for the admission of the solvent, and terminating in the hollow axle, which fits snugly through a hole at the center of the brass plate. The bowl may be drawn firmly against a felt-paper ring *g*, three-fourths inch wide, by means of the $2\frac{1}{2}$ -inch milled nut *h*, for which the hollow axle is threaded for a distance of three-fourths inch directly below the upper surface of the plate. The axle fits snugly over the shaft of the motor, to which it is locked by a slot and cross pin *i*.

The aggregate is prepared for analysis by heating it in an enamel-ware pan on the hot plate until it is sufficiently soft to be thoroughly disintegrated by means of a large spoon. Care must be taken, however, that the individual particles are not crushed. If

a section of pavement is under examination, a piece weighing somewhat over 1 kilogram may be cut off with hammer and chisel. The disintegrated aggregate is then allowed to cool, after which a sufficient amount is taken to yield on extraction from 50 to 60 grams of bitumen. It is placed in the iron bowl and a ring three-fourths of an inch wide, cut from the felt paper, is fitted on the rim, after which the brass plate is placed in position and drawn down tightly by means of the milled nut. If the bitumen is to be recovered and examined, the felt ring should be previously treated in the empty extractor with a couple of charges of carbon disulphide in order to remove any small amount of grease or resin that may be present, although a proper grade of felt should be practically free from such products. The bowl is now placed on the motor shaft and the slot and pin are carefully locked. An empty bottle is placed under the spout and 150 cubic centimeters of carbon

disulphide is poured into the bowl through the small holes. The cover is put on the copper box and, after allowing the material to digest for a few minutes, the motor is started, slowly at first in order to permit the aggregate to distribute uniformly. The speed should then be increased sufficiently by means of the regulator to cause the dissolved bitumen to flow from the spout in a thin stream. When the first charge has drained, the motor is stopped and a fresh portion of disulphide is added. This operation is repeated from four to six times with 150 cubic centimeters of disulphide. With a little experience the operator can soon gauge exactly what treatment is necessary for any given material. When the last addition of solvent has drained off, the bowl is removed and placed with the brass plate uppermost on a sheet of manila paper. The brass plate and felt ring are carefully laid aside on the paper and, when the aggregate is thoroughly dry, it can be brushed on a pan of the rough balance and weighed. The difference between this weight and the original weight taken shows the amount of bitumen extracted. The aggregate may then be tested as occasion requires.

When it is desired to recover and examine the bitumen, the apparatus shown in figure 19 will be found

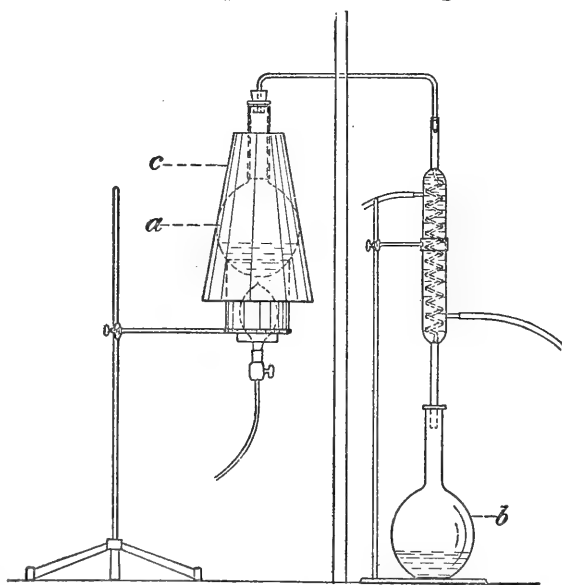


FIG. 19.—Recovery apparatus.

convenient and fairly safe for the distillation and recovery of such inflammable solvents as carbon disulphide. In the laboratory of the Office of Public Roads and Rural Engineering this apparatus is arranged so that the glass tubing passes through a stone partition between two sections of a small hood, thus keeping the distilling and receiving apparatus entirely separated.

The solution of bitumen should be allowed to stand overnight in order to permit the settling of any fine mineral matter that is sometimes carried through the felt ring in the extractor. The solution is then decanted into the flask *a*, and the solvent is driven off by means of heat from an incandescent lamp until the residue is of a thick sirupy consistency. Meanwhile the solvent is condensed and recovered in the flask *b*. The residue is poured into an 11-centimeter

porcelain evaporating dish and evaporated on a steam bath. The most scrupulous care must be taken at all times that no flames are in its immediate vicinity. Evaporation is carried on at a gentle heat, with continual stirring, until foaming practically ceases. It is advisable to have a large watch glass at hand to smother the flames quickly should the material ignite. As the foaming subsides, the heat of the steam bath may be gradually raised, and evaporation is continued until the bubbles beaten or stirred to the surface of the bitumen fail to give a blue flame or odor of sulphur dioxide when ignited by a small gas jet. The dish of bitumen should then be set in a hot-air oven maintained at 105° C. for about an hour, after which it is allowed to cool. Its general character is noted and any tests for bitumens that are necessary are then made upon it.

GRADING THE MINERAL AGGREGATE. *

EQUIPMENT.

- 1 set of 8-inch stone sieves with circular openings of $1\frac{1}{2}$, $1\frac{1}{4}$, 1, $\frac{3}{4}$, $\frac{1}{2}$, and $\frac{1}{4}$ inches, respectively.
- 1 set of 8-inch brass sand sieves of 10, 20, 30, 40, 50, 80, 100, and 200 mesh, respectively, with pan and cover.
- 1 rough balance, capacity 1 kilogram, sensitive to 0.1 gram.
- 1 $1\frac{1}{2}$ -inch stiff flat brush.
- Several sheets of manila paper.

METHOD.

While a mechanical sifter is employed in the Office of Public Roads and Rural Engineering, the following hand method is given for the benefit of those who have not a machine of this character available. When a machine is used its method of operation should be checked against the hand method described below to obtain practically equivalent results.

For aggregates containing particles too large to pass a 10-mesh screen, the stone sieves are used, and are stacked in their regular order over a sheet of heavy paper, with the largest size required on top. The weighed amount of stone is placed on the largest sieve and is carefully protected from drafts which might carry away any of the fine material. The upper sieve is then removed from the stack and shaken over a large sheet of paper until no more particles come through. The material thus retained, including any fragments caught in the meshes of the sieve, is weighed and that which passes is added to the contents of the succeeding sieve. This operation is repeated with each succeeding sieve.

When grading sands or fine aggregates, it is customary to take a 100-gram sample in order that the weights may give direct percentages to tenths of 1 per cent. The sieves are stacked in regular order with the 200-mesh sieve resting on the pan. The sample is brushed on the

top sieve, after which the cover is put on and the stack agitated for about five minutes with both rocking and circular shaking. Each sieve is removed in order, and shaken and tapped on a clean piece of paper until no appreciable amount of material comes through. All lumps are broken up by crushing them against the side of the sieve with the finger or a small spatula. The contents of the sieve are emptied into the pan of the balance. All particles caught in the mesh are removed by brushing across the underside of the sieve and are added to the contents of the pan. As great opportunity exists for wide variations in the results of sand gradings made by different persons, owing to the possibility of always getting a little more material to pass by continued shaking, it is well for the novice to repeat his sifting on any given mesh, after having weighed it, in order to see what further loss he can produce. If his judgment has not erred, several minutes' further sifting should not produce a loss of over 0.5 gram.

Where coarse aggregates have considerable material passing a 10-mesh sieve and it is desired to grade this material further, it should be weighed and well mixed, quartered, if necessary, and a 100-gram sample should be passed through the sand sieves. From the percentages so obtained and the weight of material passing the 10-mesh sieve, the percentages of the total aggregate which these finer materials represent may be calculated.

The Office of Public Roads and Rural Engineering has adopted the following recommendations of the Committee on Standard Tests for Road Materials of the American Society for Testing Materials as to the size of wire for standard sand sieves:

Mesher per linear inch:	Diameter of wire, inches.	Mesher per linear inch:	Diameter of wire, inches.
10.....	0.027	50.....	0.009
20.....	.0165	80.....	.00575
30.....	.01375	100.....	.0045
40.....	.01025	200.....	.00235

DETERMINATION OF VOIDS IN THE MINERAL AGGREGATE.

EQUIPMENT.

- 1 1,000-cubic-centimeter graduated glass cylinder.
- 1 500-cubic-centimeter graduated glass cylinder.
- 2 pieces brass tubing ($\frac{1}{4}$ -inch bore and 2 inches long).
- 1 wooden block mounted with soft rubber pad.
- 1 iron support with condenser clamp.
- 3 feet rubber tubing.
- 1 pinchcock.
- 1 $\frac{1}{4}$ -inch stiff flat brush.
- 1 small tin scoop.
- 2 sheets of manila paper.

METHOD.

The cylinders are constructed for this purpose by drilling a hole in the center of the bottom of each. This hole should be slightly larger than the outside diameter of the brass tubing, one end of which is cemented into it by means of a litharge and glycerin mixture. The upper end of the tube should be flush with the inside of the bottom of the graduated cylinder and in the large cylinder a piece of 200-mesh wire gauze should be soldered over the end of the tube to prevent fine material passing through.

The apparatus is set up as shown in figure 20, with the pinchcock on the rubber tubing closed. The small cylinder is filled with kerosene, after which the pinchcock is slowly

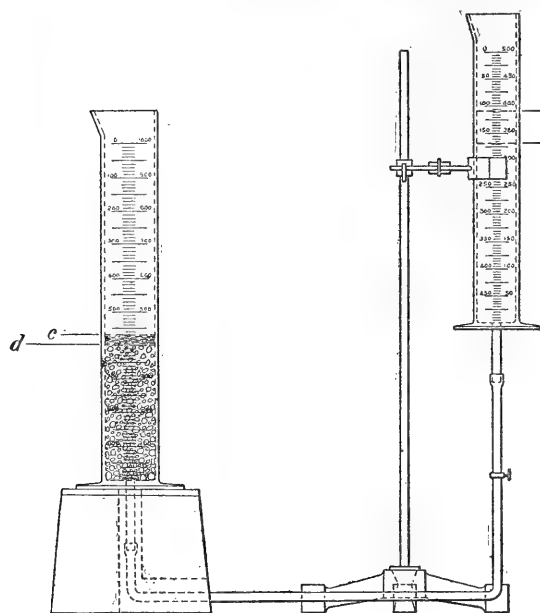


FIG. 20.—Apparatus for determining voids in the mineral aggregate.

opened in order to permit the kerosene to force any air from the tubing and to come flush with the bottom of the large cylinder. The pinchcock is then closed.

The aggregate is thoroughly mixed and quartered, if necessary, until a representative sample of material of at least 300 cubic centimeters volume is obtained. This sample of aggregate is poured into the large cylinder, a scoopful at a time, with a light

tamping of the cylinder against the rubber pad in order to compact the material. Best results are usually obtained by making a cylinder of manila paper inside the glass cylinder, and introducing the aggregate inside the paper. The paper can then be slowly withdrawn while the glass cylinder is being lightly tamped. Segregation of the several sizes of material must be avoided, and any fine material remaining on the paper should be brushed off and added to the aggregate.

When the aggregate in the large cylinder has reached its maximum state of compaction, the volume of kerosene in the small cylinder is read, the pinchcock is opened and the elevation of the small cylinder so regulated as to permit the kerosene to slowly percolate upward through the aggregate, until it has reached a point 20 or 30 cubic centi-

meters above the top of the aggregate. The meniscus of the kerosene in each cylinder and the volume of aggregate is then noted. The percentage of voids is calculated as follows:

a equals initial volume of kerosene in small cylinder.

b equals final volume of kerosene in small cylinder.

c equals meniscus of kerosene in large cylinder.

d equals apparent volume of aggregate.

Percentage of voids equals $\frac{(a-b)-(c-d)}{d}$

In some cases the kerosene fails to expel all the air from the aggregate, and this fact will be evidenced by bubbles coming to the surface if the aggregate is stirred with a long thin metal rod after the final readings are taken. Accurate results under such conditions are obtained by stirring the aggregate until bubbles cease to appear. This will, of course, yield a lower reading on the meniscus of the kerosene in the large cylinder, but the original reading on the volume of rock should be taken.

METHODS OF EXAMINING BITUMINOUS EMULSIONS.

The exact determination of the constituents of a bituminous emulsion is usually attended with considerable difficulty and no predetermined scheme can be made applicable to all materials of this character. In a number of cases, however, the following method has yielded satisfactory and fairly accurate results.

In order to break up the emulsion, a 20-gram sample is digested on a steam bath with 100 cubic centimeters of $\frac{N}{2}$ alcoholic potash. The digestion is carried out in a flask with a reflux condenser for about 45 minutes. The solution is filtered and the precipitate washed with 95 per cent alcohol. The filtrate is evaporated to dryness, after which the residue is taken up with hot water and any insoluble matter is filtered off. The aqueous solution, which contains the potassium soaps of the fatty acids, is acidified with dilute sulphuric acid and then shaken in a separatory funnel with petroleum ether. The aqueous portion is drawn off and the ethereal layer shaken up with cold water and washed twice, after which it is evaporated in a weighed platinum or porcelain dish to constant weight, first over a steam bath and then in a drying oven at 105° C. The residue consists of the fatty and resin acids present in the emulsion.

The percentage of water in the emulsion is determined by distilling a 100-gram sample in the retort used for the dehydration of tars. The distillation is carried out in exactly the same manner as described for crude tars until the volume of water in the receiver shows no further increase. Any oils that come over are thoroughly mixed with the material remaining in the retort.

A 2-gram sample of this dehydrated material is extracted with carbon disulphide as described in the method for the determination of bitumen soluble in carbon disulphide, and in this manner the organic matter insoluble in carbon disulphide can be determined. A 1-gram sample of the dehydrated material is ignited. The ash will contain any inorganic matter from the bitumen as well as the fixed alkali present in the soap. The results are, of course, all calculated on a basis of the original material.

Many emulsions contain ammonia, and when this is present a second distillation of the material is necessary. This is carried out on a 100-gram sample in exactly the same manner as described for the determinations of water, excepting for the fact that 40 cubic centimeters of a 10 per cent solution of caustic potash is added to the contents of the retort before beginning the distillation. The distillate is collected in a measured volume of $\frac{N}{2}$ sulphuric acid. When the distillation is completed the excess of acid is titrated with $\frac{N}{2}$ caustic potash, and the ammonia thus determined.

Having determined all constituents as above noted, it is assumed that the difference between their sum and 100 per cent is bitumen, which amount is reported accordingly.

APPENDIX.

LABORATORY EQUIPMENT.

The necessary equipment for a small laboratory about to engage in the ordinary routine testing and inspection of bituminous materials is given in the following list. The maximum cost, exclusive of platinum ware, solvents, and chemicals, should not exceed \$300, and the material could no doubt be purchased at a lower figure by securing bids on the entire equipment from several of the chemical supply houses.

For the extraction of bituminous aggregates, the recovery of the bitumen, and examination of the aggregates, the additional equipment described for that work will be required at an additional cost of approximately \$150.

APPARATUS.

- 1 analytical balance, capacity 100 grams, sensitive to 0.1 milligram.
- 1 set of weights, 50 grams to 5 milligrams, with rider.
- 1 rough balance, capacity 1 kilogram, sensitive to 0.1 gram.
- 1 stop watch.
- 1 Engler viscosimeter.
- 1 penetrometer, with seconds pendulum or metronome.
- 1 New York State Board of Health oil tester.
- 1 open cup oil tester with Bunsen burner.
- 1 aluminum float with 3 brass collars.
- 1 cubical brass mold.
- 1 brass plate 5 by 8 centimeters.
- 1 metal cover for melting point apparatus.
- 1 constant temperature oven.
- 1 thermo-regulator.
- 1 hot plate 14 by 18 inches.
- 1 steam bath.
- 1 small drying oven.
- 6 Bunsen burners.
- 1 pinchcock.
- 4 iron tripods.
- 4 iron ring supports.
- 3 rings for ring support, 7.5 centimeters in diameter.
- 3 condenser clamps.
- 3 burette clamps.
- 6 pieces of wire gauze, 10 by 10 centimeters.
- 2 enamel-ware dishes, 3 inches deep by 9 inches in diameter.
- 1 tin shield.
- 6 1-pint tin cups, seamless.
- 6 1-quart tin cups, seamless.
- 12 tin boxes, 6 centimeters in diameter by 2 centimeters deep.

- 6 tin boxes, 5 centimeters in diameter by 3.5 centimeters deep.
- 1 metal kitchen spoon.
- 1 $\frac{1}{2}$ -pint iron retort.
- 1 piece iron tubing, 30 inches long.
- 1 copper still, with steel clamps, inside dimensions 6 by $3\frac{1}{2}$ inches.
- 1 ring burner to fit copper still.
- 1 10-centimeter steel spatula.
- 1 crucible tongs.
- 1 hammer.
- 1 $\frac{3}{4}$ -inch cold chisel.
- 1 $1\frac{1}{2}$ -inch stiff flat brush.
- 1 triangular file.
- 1 small round file.
- 1 set of cork borers, Nos. 1 to 12.
- 1 brass filter (vacuum) pump.
- 1 piece of wire, 20 centimeters long (No. 12 Brown & Sharpe gauge).
- 3 chemical thermometers reading from -10° C. to 110° C.
- 3 chemical thermometers reading from 0° C. to 250° C.
- 2 chemical thermometers reading from 0° C. to 400° C.
- 4 hydrometers, 0.800 to 0.900; 0.900 to 1.000; 1.000 to 1.200; 1.200 to 1.400.
- 1 hydrometer jar, 350 by 50 millimeters.
- 1 special pycnometer.
- 6 250 cubic centimeter beakers, low form.
- 6 150 cubic centimeter beakers, low form.
- 2 800 cubic centimeter beakers, low form.
- 2 400 cubic centimeter beakers, tall form, without lip.
- 1 10-centimeter crystallizing dish, deep, straight sides.
- 1 5-centimeter crystallizing dish.
- 12 100 cubic centimeter Erlenmeyer flasks.
- 2 150 cubic centimeter Erlenmeyer flasks.
- 2 500 cubic centimeter flasks with side neck for filtering under pressure.
- 6 250 cubic centimeter Engler distillation flasks of special dimensions.
- 1 short condenser.
- 1 separatory funnel with stopcock.
- 4 500 cubic centimeter wash bottles, with tubulated glass stopper ground into neck for solvents.
- 1 1,000 cubic centimeter wash bottle for water.
- 6 100 cubic centimeter glass cylinders, graduated to 1 cubic centimeter.
- 6 25 cubic centimeter glass cylinders, graduated to 0.2 cubic centimeter.
- 3 10 cubic centimeter glass cylinders with ground-glass stoppers graduated to 0.2 cubic centimeter.
- 1 150-millimeter desiccator with porcelain plate.
- 1 filter tube for Gooch crucible 3.9 centimeters in diameter.
- 1 object glass.
- 1 freezing apparatus.
- 1 glass connecting tube.
- 1 pound of light glass tubing, assorted.
- 1 pound of glass rods, assorted.
- 2 rubber stoppers, No. 8, with one hole.
- 2 rubber stoppers, No. 1, with one hole.
- 5 pounds of rubber gas tubing, $\frac{1}{4}$ inch internal diameter.
- 1 foot of rubber tubing, 1 inch diameter, for Gooch crucibles.
- 5 pounds of heavy asbestos paper.
- Corks, assorted.

PLATINUM.

1 triangle, 5 centimeter sides (10 to 12 grams), or 1 nichrome triangle.

1 Gooch crucible, as specified (20 to 25 grams) for solubility determinations (may be porcelain).

1 crucible with tight-fitting, flanged lid (about 25 grams) for fixed carbon determinations.

SOLVENTS AND CHEMICALS

Carbon disulphide, chemically pure.

86° Baumé paraffin naphtha, distilling between 40° C. and 65° C.

Carbon tetrachloride, chemically pure.

Ether (Squibb's).

Alcohol, absolute (Squibb's).

Dimethyl sulphate.

Naphthalene (C. P.).

Benzophenone (C. P.).

Cottonseed oil.

Mercuric chloride or nitrate.

Mercury.

Ammonium carbonate (C. P.).

Calcium chloride, granular for desiccator.

Asbestos, pure long-fiber amphibole.

Metric conversion tables.

Length.		Capacity.		Mass.	
Inches.	Millimeters.	United States liquid ounces.	Cubic centimeters.	Avoirdupois ounces.	Grams.
$\frac{1}{16}$ = 0.0312	0.7938	1.	29.574	1.	28.3495
$\frac{1}{8}$ = .0625	1.5875	2.	59.147	2.	56.6991
$\frac{3}{16}$ = .1250	3.1750	3.	88.721	3.	85.0486
$\frac{1}{4}$ = .2500	6.3500	4.	118.295	4.	113.3981
$\frac{5}{16}$ = .5000	12.7000	5.	147.869	5.	141.7476
1.	25.4001	6.	177.442	6.	170.0972
2.	50.8001	7.	207.016	7.	198.4467
3.	76.2002	8.	236.590	8.	226.7962
4.	101.6002	9.	266.163	9.	255.1457
5.	127.0003	16 = 1 pt. . .	473.18	16 = 1 lb. . .	453.59
6.	152.4003	32 = 1 qt. . .	946.36	0.3527.	10
7.	177.8004	128 = 1 gal. .	3,785.43	.7055.	20
8.	203.2004	0.3381.	10	1.0582.	30
9.	228.6005	.6763.	20	1.4110.	40
		1.0144.	30	1.7637.	50
		1.3526.	40	2.1164.	60
		1.6907.	50	2.4692.	70
		2.0288.	60	2.8219.	80
		2.3670.	70	3.1747.	90
		2.7051.	80	3.5270.	100
		3.0432.	90	35.27.	1,000 = 1 kilogram.
		3.3810.	100		
		33.81.	1,000 = 1 liter.		
0.3937	1 = 10 mm.				
.7874	2				
1.1811	3				
1.5748	4				
1.9685	5				
2.3622	6				
2.7559	7				
3.1496	8				
3.5433	9				

Comparison of degrees Baumé and specific gravity.

(Liquids lighter than water.)

$$(1) \text{ Sp. gr.} = \frac{140}{130 + ^\circ\text{B.}} \text{ at } 15.5^\circ \text{C.} \quad (2) ^\circ\text{B.} = \frac{140}{\text{Sp. gr.}} - 130 \text{ at } 15.5^\circ \text{C.}$$

°B.	Sp. gr.	°B.	Sp. gr.	°B.	Sp. gr.	°B.	Sp. gr.
10	1.0000	31	0.8695	52	0.7692	73	0.6896
11	.9929	32	.8641	53	.7650	74	.6853
12	.9859	33	.8588	54	.7609	75	.6829
13	.9790	34	.8536	55	.7567	76	.6796
14	.9722	35	.8484	56	.7526	77	.6763
15	.9655	36	.8433	57	.7485	78	.6731
16	.9589	37	.8383	58	.7446	79	.6698
17	.9523	38	.8333	59	.7407	80	.6666
18	.9459	39	.8284	60	.7368	81	.6635
19	.9395	40	.8235	61	.7330	82	.6604
20	.9333	41	.8187	62	.7292	83	.6573
21	.9271	42	.8139	63	.7254	84	.6542
22	.9210	43	.8092	64	.7216	85	.6511
23	.9150	44	.8045	65	.7179	86	.6482
24	.9090	45	.8000	66	.7143	87	.6452
25	.9032	46	.7954	67	.7107	88	.6422
26	.8974	47	.7909	68	.7071	89	.6393
27	.8917	48	.7865	69	.7035	90	.6363
28	.8860	49	.7821	70	.7000		
29	.8805	50	.7777	71	.6965		
30	.8750	51	.7734	72	.6931		

Comparison of Centigrade and Fahrenheit degrees.

$$(1) ^\circ\text{F.} = \frac{9}{5} ^\circ\text{C.} + 32. \quad (2) ^\circ\text{C.} = \frac{5(^{\circ}\text{F.} - 32)}{9}.$$

C.	F.	C.	F.	C.	F.	C.	F.	C.	F.	C.	F.
0	32.0	38	100.4	76	168.8	114	237.2	152	305.6	190	374.0
1	33.8	39	102.2	77	170.6	115	239.0	153	307.4	191	375.8
2	35.6	40	104.0	78	172.4	116	240.8	154	309.2	192	377.6
3	37.4	41	105.8	79	174.2	117	242.6	155	311.0	193	379.4
4	39.2	42	107.6	80	176.0	118	244.4	156	312.8	194	381.2
5	41.0	43	109.4	81	177.8	119	246.2	157	314.6	195	383.0
6	42.8	44	111.2	82	179.6	120	248.0	158	316.4	196	384.8
7	44.6	45	113.0	83	181.4	121	249.8	159	318.2	197	386.6
8	46.4	46	114.8	84	183.2	122	251.6	160	320.0	198	388.4
9	48.2	47	116.6	85	185.0	123	253.4	161	321.8	199	390.2
10	50.0	48	118.4	86	186.8	124	255.2	162	323.6	200	392.0
11	51.8	49	120.2	87	188.6	125	257.0	163	325.4	201	393.8
12	53.6	50	122.0	88	190.4	126	258.8	164	327.2	202	395.6
13	55.4	51	123.8	89	192.2	127	260.6	165	329.0	203	397.4
14	57.2	52	125.6	90	194.0	128	262.4	166	330.8	204	399.2
15	59.0	53	127.5	91	195.8	129	264.2	167	332.6	205	401.0
16	60.8	54	129.2	92	197.6	130	266.0	168	334.4	206	402.8
17	62.6	55	131.0	93	199.4	131	267.8	169	336.2	207	404.6
18	64.4	56	132.8	94	201.2	132	269.6	170	338.0	208	406.4
19	66.2	57	134.6	95	203.0	133	271.4	171	339.8	209	408.2
20	68.0	58	136.4	96	204.8	134	273.2	172	341.6	210	410.0
21	69.8	59	138.2	97	206.6	135	275.0	173	343.4	220	428.0
22	71.6	60	140.0	98	208.4	136	276.8	174	345.2	230	446.0
23	73.4	61	141.8	99	210.2	137	278.6	175	347.0	240	464.0
24	75.2	62	143.6	100	212.0	138	280.4	176	348.8	250	482.0
25	77.0	63	145.4	101	213.8	139	282.2	177	350.6	260	500.0
26	78.8	64	147.2	102	215.6	140	284.0	178	352.4	270	518.0
27	80.6	65	149.0	103	217.4	141	285.8	179	354.2	280	536.0
28	82.4	66	150.8	104	219.2	142	287.6	180	356.0	290	554.0
29	84.2	67	152.6	105	221.0	143	289.4	181	357.8	300	572.0
30	86.0	68	154.4	106	222.8	144	291.2	182	359.6	350	662.0
31	87.8	69	156.2	107	224.6	145	293.0	183	361.4	400	752.0
32	89.6	70	158.0	108	226.4	146	294.8	184	363.2	450	842.0
33	91.4	71	159.8	109	228.2	147	296.6	185	365.0	500	932.0
34	93.2	72	161.6	110	230.0	148	298.4	186	366.8	550	1,022.0
35	95.0	73	163.4	111	231.8	149	300.2	187	368.6	600	1,112.0
36	96.8	74	165.2	112	233.6	150	302.0	188	370.4	650	1,202.0
37	98.6	75	167.0	113	235.4	151	303.8	189	372.2	700	1,292.0

FORMS FOR REPORTING TESTS.

FILE CARDS.

Form 93.—Rev.

UNITED STATES DEPARTMENT OF AGRICULTURE,
OFFICE OF PUBLIC ROADS AND RURAL ENGINEERING,
Washington, D. C.

Sample No.

Report on

Identification mark

Known as

Submitted by

Examined for

General character

Specific gravity 25°/25°C

Melting point °C

Float test at °C; at °C

Viscosity Engler at °C c. c. specific

Bitumen soluble in CS₂Free carbon (insoluble in CS₂)

Ash

Distillation—

Water

First light oils (-110°C)

Second light oils (110-170°C)

Heavy oils (170-270°C)

Heavy oils (270-300°C)

Pitch residue

Total

% by vol.	% by wt.	Char-acter.

Remarks

Date received, Date reported

Analyst

Form 77.—Rev.

UNITED STATES DEPARTMENT OF AGRICULTURE,
OFFICE OF PUBLIC ROADS AND RURAL ENGINEERING,
Washington, D. C.

Sample No.

Report on

Identification mark

Known as

Submitted by

Examined for

General character

Specific gravity 25°/25°C

Melting point °C

Flash point °C

Burning point °C

Viscosity at °C; c. c. specific

Ductility at 25°C. (cm.)

Float test at °C. time; at °C. time

Penetration at 25°C. (mm.)

Loss at °C hours

Character of residue

Consistency of residue (Float test at °C.
Penetration at 25 °C. (mm.)Bitumen soluble in CS₂

Organic matter insoluble

Inorganic matter insoluble

% of total bitumen insol. in 80° naphtha

% of total bitumen insol. in CCl₄

% fixed carbon

Remarks

Date received, Date reported

Analyst

Form 67.—Rev.

UNITED STATES DEPARTMENT OF AGRICULTURE,
OFFICE OF PUBLIC ROADS AND RURAL ENGINEERING,
Washington, D. C.

Sample No.

Report on

Identification mark

Known as

Submitted by

Examined for

UNITED STATES DEPARTMENT OF AGRICULTURE



BULLETIN No. 315



Contribution from Office of Markets and Rural Organization,
CHARLES J. BRAND, Chief

Washington, D. C.



October 23, 1915

CANTALOUPE MARKETING IN THE LARGER CITIES, WITH CAR-LOT SUPPLY, 1914.

By WELLS A. SHERMAN, *Specialist in Market Surveys*; A. DEXTER GAIL, JR., *Assistant in Market Surveys*, and FAITH L. YEAW, *Laboratory Aid*.

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INTRODUCTION.

In the market survey work carried on by the Office of Markets and Rural Organization considerable attention has been given to the marketing of cantaloupes. During the summer of 1914 a study was made in a number of the larger markets of the East and Middle West in an effort to determine the factors that underlie the successful handling and marketing of this crop.

The 1914 season was a very disastrous one to practically all cantaloupe-shipping sections, and, while the marketing difficulties encountered were, in most cases, the same as in former years, they were accentuated greatly by unusual conditions surrounding crop production and consumptive demand.

EXTENT OF INVESTIGATIONS.

To secure comprehensive data, representatives of the office ¹ were located for various lengths of time in Chicago, St. Louis, Cleveland, Pittsburgh, Milwaukee, St. Paul, New Haven, Cambridge, Hartford, and Kansas City. In addition, general information was secured in Buffalo and Minneapolis.

¹ These studies were carried on by the following market reporters: J. W. Fisher, jr., J. H. Collins, R. Maynard Peterson, G. P. Warber, Grafton L. Wilson, Joseph W. McNaughton, and M. M. Stewart.

NOTE.—This bulletin should be of general interest to cantaloupe growers, shippers, dealers, and consumers, and to transportation companies.

The distribution of a number of cars of cantaloupes was traced so far as was possible from the car-lot receiver in the market to the consumer, records being made of all changes in possession or ownership and of added charges. In a number of instances it was possible to secure these data from the time the carload of cantaloupes left the point of production. While practical difficulties made it impossible to make the record complete, an endeavor was made to secure the following items of information, so far as they applied, on each car traced: Car number and initials; point of origin; consignor; consignee; selling fees of the marketing association, distributor, local buyer, or solicitor; date of shipment; date of arrival on market; date car was opened; date released; freight; refrigeration; switching charges; demurrage; condition of stock on arrival; cartage charges; gross profits of brokers, wholesalers or commission merchants, jobbers and retailers.

It can be seen readily that as the distribution of a car of cantaloupes in a city progressed, the difficulty of tracing the individual crates greatly increased. The cooperation of the wholesaler or the commission merchant who received the car was all that was required to secure a record of the initial sales, but as the carload was distributed among scores of jobbers, retail grocers, fruit stands, hucksters, and push-cart men, it became impossible for one worker to follow all the crates. Consequently the part of the carload traced through the retailer was small when compared with the number of crates sold by the car-lot receivers and jobbers on which it was possible to secure a record.¹

In addition to the above outlined work on specific cars of cantaloupes, observations were made of all apparent factors which affected the cantaloupe market, either favorably or adversely, in the cities visited, such as the comparative receipts from the various competing areas, the order of the appearance of these shipments on the market, the quality and quantity of receipts, the preference of particular markets for the different varieties and grades of cantaloupes, the margin of profit, and general weather conditions.

SYSTEMS OF DISTRIBUTION WITHIN CITIES.

Where investigations were made, it was found that in the car-lot marketing of cantaloupes there were several channels of distribution after the car reached its destination. The three routes or channels here given seemed best defined:

I.	II.	III.
1. Broker. 2. Wholesaler or commission merchant. 3. Jobber. 4. Retailer. 5. Consumer.	1. Broker. 2. Jobber. 3. Retailer. 4. Consumer.	1. Wholesaler or commission merchant. 2. Jobber. 3. Retailer. 4. Consumer.

¹ Acknowledgment is made of the helpful spirit shown by the large number of produce merchants who aided in the above work by allowing the office free access to their books, sales records, etc., and otherwise cooperated in securing necessary data.

Many firms, particularly those located in other than the larger markets, combine the functions of the wholesaler and jobber¹ by selling either to the jobber or the retailer as the occasion demands. Thus, for instance, in the first channel cited, it is not correct to assume that there are necessarily four separate agencies of distribution concerned. However, it must be understood that when a firm sells to both jobbers and retailers, the prices named to the latter, who usually buy in small quantities, are, as a rule, higher than those charged the jobbers.

In most markets the broker figures more prominently in the distribution of western cantaloupes than of eastern stock, and it is safe to say that a much larger percentage of cars shipped from the West are handled by city firms on consignment than is the case with those originating at points east of the Mississippi. The practice of wholesale buying of eastern cantaloupes may be partially explained by their lower delivered cost compared with that of western stock. The dealer has to invest less money and his risks are fewer.

FACTORS WHICH INFLUENCE PRICES.

CAR-LOT RECEIPTS.

The daily receipts of car lots of cantaloupes naturally play an important part in determining prices. On the average large market, these receipts are from several widely separated producing sections.

Table 1 shows how far-distant producing sections will compete with near-by areas on the same market in spite of great differences in freight and transportation rates.

TABLE 1. --States from which cantaloupes were quoted in New York and Chicago on August 1, 8, and 15, 1914.

NEW YORK CITY.			CHICAGO.		
Aug. 1.	Aug. 8.	Aug. 15.	Aug. 1.	Aug. 8.	Aug. 15.
Maryland. Virginia. North Carolina. Arizona. Nevada.	New Jersey. Delaware. Maryland. Virginia. Arizona. Nevada. Texas.	New Jersey. Delaware. Maryland. Virginia. North Carolina. Texas. Nevada. California.	Indiana. Illinois. Arkansas. Nevada. Arizona. California.	Illinois. Michigan. Indiana. Texas. New Mexico. Arizona. Nevada. California.	Illinois. Michigan. Indiana. Delaware. Maryland. Texas. New Mexico. California.

Thus it can be seen that there is a great range in the location of the shipping sections and in the distances which the cantaloupes must be transported before being offered for sale. Cantaloupes from Cali-

¹ The use of the terms "wholesaler" and "jobber" in this bulletin conforms to the meaning given them in the eastern and some of the middle-western markets where the wholesaler buys in large quantities, usually in car lots, and disposes of most of his stock in sales of good size to jobbers and large retailers. The jobber, as a rule, buys in smaller amounts from the car-lot receiver and sells mainly to the retail trade. See U. S. Department of Agriculture Bul. 267, *Methods of Wholesale Distribution of Fruits and Vegetables on Large Markets*. 1915.

fornia were on the New York market with those from Maryland; a section distant more than 3,000 miles competing with a shipping area only some 200 miles away. On August 15, Texas points, 2,100 to 2,200 miles distant from New York City, were sending their melons to compete with those from New Jersey. New Mexico and Nevada compete with Indiana and Illinois for preference on the Chicago market. A good example of the competition between different producing areas is shown by the conditions on August 15 in the city of Chicago, when the melons from eight different States were quoted as being in direct competition with each other. It is interesting to note the wide area represented with Michigan in the North,

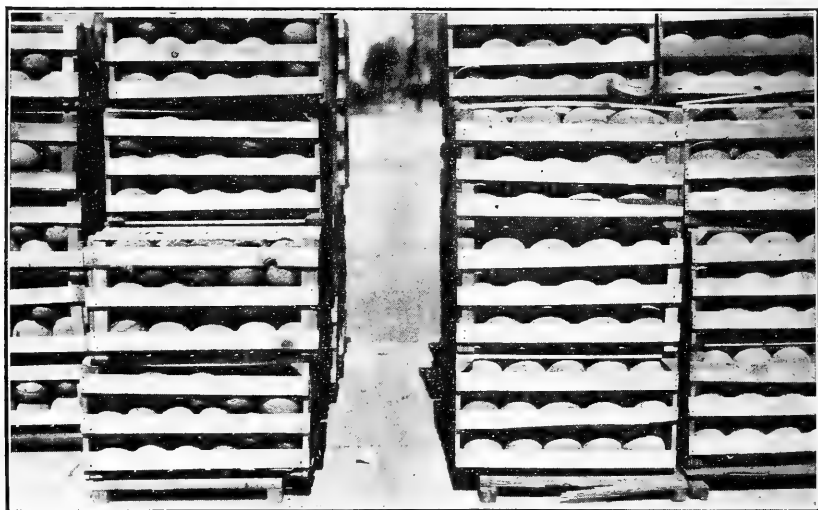


FIG. 1.—Well graded and packed cantaloupes on the right. Crates at the left show shrinkage and the melons are jumbled, due to slack packing at point of production. Both lots were being sold by one commission firm, the crates at the right at a substantial profit and the ones at the left for less than transportation charges.

Texas in the Southwest, California in the West, and Delaware and Maryland in the East.

There are important reasons why competition from such widely separated areas is possible. Transportation and refrigeration facilities are such that it is now possible to deliver these shipments from distant points to eastern markets in practically as sound condition as that in which local supplies arrive. The question of competition narrows itself to a comparison of appearance and quality of the melons (figs. 1 and 2) and the difference in freight and refrigeration rates from these competing areas. If the melons from California and Texas are not superior in some way to those from Delaware, Maryland, and Michigan, then they can not profitably enter the same market, unless the cost of production is sufficiently low to offset the increased freight and refrigeration charges.

SUPERIORITY OF WESTERN CANTALOUPE.

A close study of the larger markets leaves no doubt that in a general way higher prices are paid for cantaloupes grown under irrigation than for those grown under rainfall. While the latter may be of equal quality at times, the quality varies more from week to week with changes in temperature, rainfall, and sunshine at the point of origin.

If irrigation is controlled properly the western cantaloupes never lie on wet ground, and are almost entirely free

from the unattractive white side which characterizes most of those grown under rainfall, especially in very wet seasons.

Table 2 gives the car-lot rates for freight and refrigeration from several well-known cantaloupe shipping sections to 12 of the large markets in the East and Middle West.

TABLE 2.—*Car-lot freight and refrigeration rates on cantaloupes in effect during the spring of 1915.*

[These rates are subject to change on legal notice.]

To—	From—											
	Brawley, El Centro, and Imperial, Cal.				Mesa, Ariz.				Las Cruces, N. Mex.			
	Freight service.		Express service.		Freight service.		Express service.		Freight service.		Express service.	
	Freight per 100 pounds.	Refrigeration per car.	Express per 100 pounds.	Refrigeration per car.	Freight per 100 pounds.	Refrigeration per car.	Express per 100 pounds.	Refrigeration per car.	Freight per 100 pounds.	Refrigeration per car.	Express per 100 pounds.	Refrigeration per car.
Albany, N. Y.	\$1.25	\$112.50	\$2.50	\$105.00	\$1.25	\$115.00	(a)	(a)	\$0.985	\$72.50	(a)	(a)
Baltimore, Md.	1.25	112.50	2.50	105.00	1.25	115.00	\$2.50	\$105.00	.97	72.50	\$1.75	\$75.00
Boston, Mass.	1.25	117.50	2.75	110.00	1.25	120.00	2.75	110.00	1.04	75.00	2.00	75.00
Buffalo, N. Y.	1.15	107.50	2.50	105.00	1.15	110.00	2.50	105.00	.86	65.00	1.75	75.00
Chicago, Ill.	1.00	97.50	2.25	90.00	1.00	100.00	2.25	90.00	.65	b .60	1.25	55.00
Cleveland, Ohio.	1.15	107.50	2.50	100.00	1.15	110.00	2.50	100.00	.83	65.00	1.75	70.00
New York City, N. Y.	1.25	112.50	2.50	105.00	1.25	115.00	2.50	105.00	1.00	72.50	1.75	75.00
Philadelphia, Pa.	1.25	112.50	2.50	105.00	1.25	115.00	2.50	105.00	.98	72.50	1.75	75.00
Pittsburgh, Pa.	1.15	107.50	2.50	100.00	1.15	110.00	2.50	100.00	.86	65.00	1.75	70.00
Rochester, N. Y.	1.25	112.50	2.50	105.00	1.25	115.00	2.50	105.00	.91	72.50	(a)	(a)
St. Louis, Mo.	1.00	97.50	2.25	85.00	1.00	100.00	2.25	85.00	.65	b .60	1.25	55.00
Washington, D. C.	1.25	112.50	2.50	105.00	1.25	115.00	2.50	105.00	.97	72.50	1.75	75.00

a No carload rates in effect.

b Per 100 pounds.

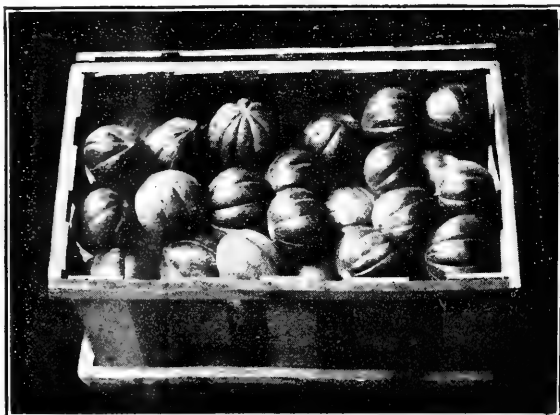


FIG. 2.—How some sections ship cantaloupes to market. These melons were ungraded for size, quality, or ripeness, and did not make an attractive appearance.

TABLE 2.—*Car-lot freight and refrigeration rates on cantaloupes in effect during the spring of 1915—Continued.*

To—	From—									
	Rockyford and Las Animas, Colo.				Brownsville, Tex.				Seaford, Del.	
	Freight service.		Express service.		Freight service.		Express service.		Freight service.	Express service.
	Freight per 100 pounds.	Refrigeration per car.	Express per 100 pounds.	Refrigeration per car.	Freight per 100 pounds.	Refrigeration per hundred weight.	Express per 100 pounds.	Refrigeration per car.	Freight per 100 pounds.	Refrigeration per package.
Albany, N. Y.	\$0.795	\$65.00	(b)	(b)	\$0.994	\$0.50	(b)	(b)	\$0.249	\$0.11
Baltimore, Md.	.78	65.00	\$1.375	\$50.00	.981	.50	\$2.00	\$65.00	.189	.095
Boston, Mass.	.85	65.00	1.625	50.00	1.051	.51	2.25	65.00	.315	.11
Buffalo, N. Y.	.635	60.00	1.25	45.00	.816	.435	1.50	60.00	.261	.11
Chicago, Ill.	.46	50.00	1.00	37.00	.65	.385	1.50	55.00	.368	.125
Cleveland, Ohio.	.605	60.00	1.25	45.00	.785	.385	1.75	60.00	.261	.125
New York City, N. Y.	.81	65.00	\$1.375	\$50.00	1.011	.50	2.00	65.00	.21	.095
Philadelphia, Pa.	.79	65.00	1.375	50.00	.991	.45	2.00	65.00	.189	.095
Pittsburgh, Pa.	.635	60.00	1.375	50.00	.816	.4025	1.75	60.00	.221	.11
Rochester, N. Y.	.72	65.00	(b)	(b)	.908	.50	2.00	65.00	.249	.11
St. Louis, Mo.	.41	50.00	.875	35.00	.58	.3075	1.25	50.00	.431	.14
Washington, D. C.	.78	65.00	1.375	50.00	.981	.50	2.00	65.00	.221	.095

^a Express company does not provide refrigerator service. If any is desired the express company will supply refrigerator cars for quantities in excess of 12,000 pounds, but shippers must furnish the ice.

^b No carload rates in effect.

^c Delivery at Jersey City only.

THE HOME-GROWN CROP.

In the immediate vicinity of many important markets a large acreage of cantaloupes is planted annually, and in 1914 a crop of unusual size was harvested. The quality of these melons was above the average, and the markets were kept well supplied with this stock throughout the local season. These cantaloupes can be placed on the home markets at a minimum of expense as there are no heavy freight and refrigeration charges to pay and in some cases the packages are returned to the grower. The saving in transportation charges is considerable, as indicated in Table 2.

In addition to this, the local growers have the great advantage of being able to offer dealers a daily supply of freshly picked melons. In many cases, in 1914, it was possible to dispose profitably of a large part of the local crop at prices which would not return the distant car-lot shipper his cost of transportation. As a result of this large home-grown supply the demand for melons shipped into many markets from distant areas of production was curtailed.

CONDITION AND QUALITY OF RECEIPTS.

As with most other highly perishable products, there is much complaint in the markets regarding deficiencies in the condition and quality of cantaloupes, both the home-grown stock and that which comes from a distance. There is no doubt that prices are greatly

depressed by the constant receipt of melons which are overripe, immature, or diseased. The channels of distribution become choked with this poor stock, which to be moved at all must be sold at prices which leave little or nothing for the grower. Even the better grades of cantaloupes do not bring their full value under these conditions, for the large quantities of melons of low quality and price give the buyer a lever to force down the price level for good stock. The disappointment resulting from purchasing poor cantaloupes so dulls the demand that the movement for the rest of the season is adversely affected.

While a great deal of stock evidences poor quality or condition when it arrives in the market, these disadvantages are greatly aggravated by the deterioration which takes place while the cantaloupes are in the hands of the dealer. There is a harmful tendency on the part of many cantaloupe receivers in the markets to encourage the shipment of greater supplies than they can handle promptly. Each day their surplus stock is held it becomes harder to sell, and in an endeavor to move it before it becomes a total loss the fresher receipts are often held back and begin to deteriorate in turn. If conditions are to be satisfactory to producer, distributor, and consumer it is essential that the supply of a fruit as highly perishable as cantaloupes be gauged to meet the consuming demands of a market, so that fresh stock may be received daily and distributed throughout a city without delay. It is just as important that the average receipts be of a quality calculated to stimulate the demand. Before this condition can be met there must be great improvement both in regard to eating qualities and soundness of the average run of cantaloupes shipped.

CANTALOUPE PACKAGES.

The containers in use undoubtedly have an influence upon the sale of cantaloupes. The most common packages are the "jumbo," "standard," "two-thirds," "pony," and "flat" crates. Different producing sections have their own ideas as to just what packages should be used, and as a result an assortment of types and sizes is found on most markets.

While this may not have been a large factor in determining 1914 cantaloupe prices, it is believed that more uniformity in the packages used would eliminate a good deal of the confusion noticed in the quoting and selling of the melons by wholesalers and jobbers, and would make possible desirable economies in their handling and shipping.

In seasons of heavy production the most active demand is for melons which are uniformly graded and packed, of standard size, and put

up in standard containers (fig. 3). Under such conditions it is unprofitable, as a rule, to ship the "off sizes." The shipment of pony crates in a season such as 1914 tends to clog up the markets

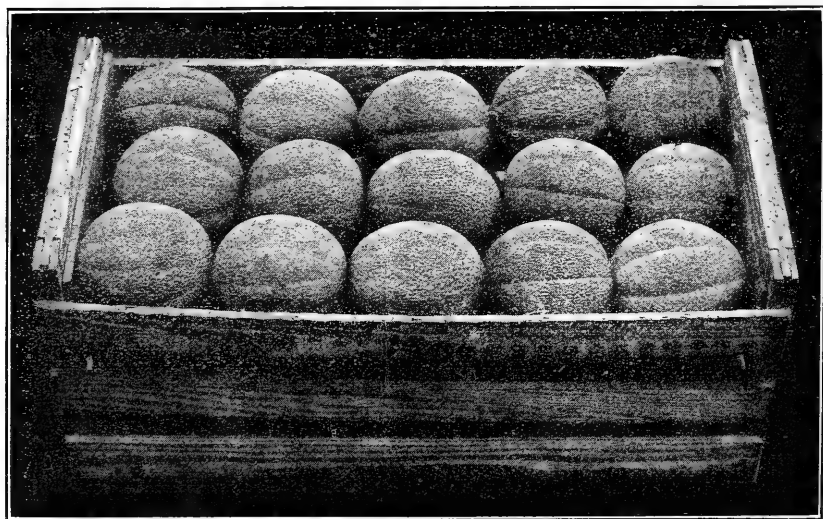


FIG. 3.—A standard crate packed with 45 well-graded melons.

with the smaller-sized fruit, which retards sales and lowers the prices on the more desirable stock.

The two packages that are used with best results are the standards, holding 45 melons (fig. 3), and the flat, holding 9 to 15 melons (fig. 4). The flat is an ideal package for the consumer if the retailer will educate him to buy in the original units. It contains no more than an



FIG. 4.—A flat crate of cantaloupes. This container is especially well adapted to the consuming trade that desires to buy in the original package.

average-sized family can use to advantage without incurring waste or decay. The use of packages of odd sizes or types should be discouraged by receivers of cantaloupes in the market. Growers who

are warned against their use should realize that the objections to such packages are well founded.

Table 3 illustrates the need for standardization of packages used in marketing cantaloupes. It shows the different types and sizes of containers which were being quoted on the Milwaukee market from three States on one day during the 1914 season:

TABLE 3.—*Cantaloupe packages in use in Milwaukee on the same day.*

From Arizona:

Standard crates.....	45 melons.
Jumbo crates.....	36 or 45 jumbo melons.
Two-thirds crates.....	30 melons.
Pony crates.....	54 melons.
Standard flat crates.....	12 or 15 melons.
Pony flat crates.....	15 melons.
Jumbo flat crates.....	9 or 12 melons.

From Illinois:

Climax baskets.....	14 to 20 melons.
Flat cases.....	10 to 18 melons.
Pony cases.....	16 melons.
Crates.....	1 bushel.

From Indiana:

Standard crates.....	36 or 45 melons.
Flat—24 inches long.....	15 to 18 melons.
Flat—20 inches long.....	12 to 15 melons.
Basket crates.....	about $\frac{1}{3}$ bushel.
Climax baskets.....	14 to 20 melons.

EFFECT OF WEATHER ON DEMAND AND PRICE.

The demand for few fruits fluctuates more quickly in response to changes in weather conditions than does that for cantaloupes. Clear, hot days stimulate consumption to its maximum while a cold, rainy period acts as a decided check, often reducing demand to the point of demoralizing prices. To local growers such an occurrence is not so detrimental as it is to those far from market who may have hundreds of cars rolling, so allotted as to give each eastern city a supply which should be its maximum under best selling conditions. In such cases a few cold, rainy days in the East may so stagnate the markets that very heavy losses result.

Such conditions occurred during September, 1914, while the shipments of Colorado "pink meats" were moving heavily. From about the 10th to the 16th of the month most of the States in the North and East experienced unusually cold weather, accompanied by rain in some sections. Light frosts were reported from several points. The effect of this was to decrease to a marked extent the demand for Colorado cantaloupes and reduce to a still lower level prices which were already ruinous to the shippers.

COMPETING CROPS.

The size of other crops competing with cantaloupes was above the ordinary during the 1914 season. These crops very evidently affect the price of and demand for cantaloupes. It is difficult for those outside of the produce trade to realize to what extent the profitable marketing of one perishable crop may be hindered when a few hundred cars of a competing product are added to the average or anticipated supply. The possibility of the consumers substituting one fruit for another is a phase of marketing that must always be borne in mind in dealing with highly perishable products. Such fruits as watermelons, peaches, plums, and grapes can easily replace cantaloupes on the average table, and when the supplies of these competing fruits are abundant and prices low a noticeable weakening in the demand for cantaloupes generally is felt.

LENGTH OF SHIPPING SEASON.

The duration of the cantaloupe season has a direct influence on the question of demand. The average length of time that cantaloupes are to be found on the principal markets is four and one-half to five months. This is a long season for any fruit, and there is danger that the consumers will be tired of cantaloupes before the supply is exhausted. Many cases were found toward the close of the 1914 season where restaurants and cafés no longer included cantaloupes in their menu, although the quality was still good and prices were low. As the trade turns to other fruits it becomes increasingly difficult to effect sales of cantaloupes.

MARKET PREFERENCES.

In some markets the preferences of dealers and of the consuming public for certain kinds of melons or certain packages are pronounced. These preferences are reflected through the grocer to the jobber and through the jobber to the wholesaler or broker. In some markets pink-fleshed melons are in greater demand than the green meats, while in other cities the opposite is true. Paper-wrapped cantaloupes are preferred by the trade of some cities on account of their attractiveness, while in others the dealers object to the paper wrapper, believing that it promotes decay by retarding evaporation after the melons sweat on being taken from a refrigerator car. The wrapper also prevents easy inspection by the buyer. Some assert that as the bright-colored wrapper becomes faded by the sun and torn to allow inspection, it detracts from, rather than adds to, the appearance of the fruit.

SOME TRADE FACTORS INFLUENCING THE MARKETING OF CANTALOUPE.

A wholesale, jobbing, or retail merchant who deals in cantaloupes has a chance to demonstrate both ability and good judgment. The high degree of perishability of this fruit demands that great care be exercised in its handling. When it is possible to avoid it, cantaloupes should not be exposed to the sun or kept in a warm place. The quickest possible movement consistent with reasonable prices should be a fixed rule with every dealer.

MARGINS OF GROSS PROFIT.

In considering the results secured by following as large a part as was possible of certain cars of cantaloupes through to the consumer it must be borne in mind that the investigations made during the season of 1914 included comparatively few cars. In order to draw fair conclusions regarding the average margins of profit received by different dealers in the handling of cantaloupes it would be necessary to conduct studies covering a far greater number of cars in a larger number of markets and extending over several seasons.

No conclusions for general application can be drawn safely from the examples which follow. The results on each car must be considered as representing individual instances of cantaloupe marketing, typical only of the conditions which existed at that point during the time the car was sold. The 1914 cantaloupe season was abnormal, supplies being heavy and ruling prices exceedingly low during most of the summer.

It must be understood that in giving detailed data on the cars of cantaloupes traced the margins mentioned represent gross profits. From these profits the dealers who bought their supplies outright were compelled to deduct all overhead expenses properly chargeable against the transaction, as well as all losses due to deterioration and decay of stock. All expenses for drayage and delivery are included in the gross profit made by the various dealers except in the case of the cars handled on commission, where the drayage from the car to the commission merchant's store is, with few exceptions, charged to the shipper.

In Table 4 figures are given on all cars of standard crates or flat crates followed, where the number of crates traced through to the consumer equaled 5 per cent or more of the contents of the car.

TABLE 4.—*Compilation of data on crates of cantaloupes traced.*

THROUGH THE CAR-LOT RECEIVER.

Office record No. of car.	Contents of car.		Number of crates traced.	Per cent of total number of crates in car.	Total delivered cost to car-lot receiver. ^a	Total amount of sales.	Car-lot receiver's gross profit or loss. ^c	Average gross profit or loss per crate.	Per cent of gross profit or loss. ^c
	Total number of crates.	Type of crate.							
1	260	Standard..	260	100	\$434.60	\$495.20	\$60.60	\$0.233	13.9
2	438	do.....	438	100	559.04	371.75	<i>d</i> 187.29	<i>d</i> .428	<i>d</i> 33.5
3	360	do.....	234	65	(<i>e</i>)	424.75	29.73	.127	7.0
4	360	do.....	239	66.4	(<i>e</i>)	338.45	23.69	.099	7.0
5	871	Flats.....	871	100	(<i>e</i>)	439.68	43.97	.050	10.0
6	768	do.....	768	100	(<i>e</i>)	393.95	39.40	.051	10.0
7	756	do.....	756	100	(<i>e</i>)	400.80	28.06	.037	7.0

THROUGH JOBBERS.

Office record No. of car.	Contents of car.		Number of crates traced.	Per cent of total number of crates in car.	Total delivered cost to jobbers. ^{ab}	Total amount of sales.	Jobbers' gross profit.	Average gross profit per crate bought.	Per cent of gross profit on investment.
	Total number of crates.	Type of crate.							
1	260	Standard..	200	76.9	\$422.20	\$440.15	\$17.95	\$0.09	4.3
2	438	do.....	279	63.7	228.44	263.38	34.94	.125	15.3
3	360	do.....	24	6.7	45.94	58.50	12.56	.523	27.3
4	360	do.....	29	8.0	50.75	61.85	11.10	.383	21.8
5	871	Flats.....	548	62.9	282.98	333.45	50.47	.092	17.8
6	768	do.....			No crates sold to jobbers.				
7	756	do.....	516	68.3	270.90	313.45	42.55	.082	15.7

THROUGH RETAILERS.

Office record No. of car.	Contents of car.		Number of crates traced.	Per cent of total number of crates in car.	Total delivered cost to retailers. ^{a b}	Total amount of sales.	Retailers' gross profit.	Average gross profit per crate bought.	Per cent of gross profit on investment.
	Total number of crates.	Type of crate.							
1	260	Standard..	250	96.1	\$543.99	\$700.76	\$156.77	\$0.627	28.8
2	438	do.....	<i>f</i> 23	5.3	30.25	50.82	20.57	.894	68.0
3	360	do.....	29	8.1	61.20	88.76	27.56	.95	45.0
4	360	do.....	18	5.0	35.35	47.50	12.15	.675	34.3
5	871	Flats.....	<i>g</i> 212	24.3	122.79	282.90	160.11	.755	130.4
6	768	do.....	280	36.5	150.50	200.10	49.60	.177	33.0
7	756	do.....	<i>h</i> 206	27.2	135.35	239.16	103.81	.504	76.7

^a All cartage charges are treated as overhead expense to the various dealers and are included in their gross profits except those charges which accrue in hauling from the cars to the commission merchants' stores. Such cartage expense is charged against the shipper.

^b Amounts in this column include freight and express, but not cartage charges on crates sold to out-of-town "trade."

^c Car No. 2 is the only one recorded showing a loss.

^d Loss.

^e Car on commission.

^f One crate out of this number was sold to a hotel, which made a gross profit of \$6.40 on the crate, or 457.1 per cent on the investment. This reduces the average gross profit of the other retail agencies to \$0.644 per crate, or 49.1 per cent on their investment.

^g Seventy-one crates out of this number were sold to hotels, dining cars, etc., where an average gross profit of \$1.72 per crate was made, or 287.5 per cent on the investment. This reduces the average gross profit of the other retail agencies to \$0.267 per crate, or 47 per cent on the investment.

^h Twenty-six crates of this number were sold to hotels, dining cars, etc., where an average gross profit of \$1.938 per crate was made, or 245.2 per cent on the investment. This reduces the average gross profit of the other retail agencies to \$0.267 per crate, or 47 per cent on the investment.

From Table 4 and from the records of the three cars shown in Table 5 it can be seen that the average commission merchant and wholesaler suffer along with the shipper as a result of low prices and a sluggish market.

TABLE 5.—*Sales records of three cars of cantaloupes of poor quality.*

	Car 1.	Car 2.	Car 3.
Freight.....	\$84.00	\$97.15	\$151.71
Refrigeration.....	57.75	50.00	27.55
Cartage.....	7.50	7.50	7.06
Commission.....	16.63	13.44	18.09
Net to shipper.....	.46	23.91	54.04
Gross sales.....	166.34	192.00	258.45

The first car contained 300 standard crates of Arkansas cantaloupes of poor quality which arrived on the market green; 125 crates spoiled and were a total loss.

The second car contained 769 flat crates of Rockyford, Colo., cantaloupes which arrived in poor condition, spotted and soft.

There were 866 flat crates of Colorado pink meats in the third car which were held on track two weeks before being sold because of an overloaded market. When unloaded, they spoiled quickly.

In a poor season like that of 1914 the cost of handling perishable goods is as high or higher per car than is the case in a year when the market is in a healthy condition and prices are good. On the other hand, the average returns per car to the commission merchant are lower, since his gross sales, on which his selling charge or percentage of gross profit is based, are greatly reduced. The wholesaler who invests his money in the outright purchase of the cantaloupes must do his regular work of handling a car under conditions which reduce his profits in a marked way. The slow movement of the fruit means greater loss through deterioration, while the heavy receipts of melons often compel him to cut his prices in order to effect sales, thereby reducing his margin of profit. It is a well-known saying in the wholesale and commission trade that no one makes money when stuff is cheap, a statement which has been born of long experience. As a rule, the losses occasioned by a poor year are felt less keenly by the jobber and retailer. They buy in smaller quantities from day to day, and their financial risks are therefore much less.

From the data in Table 4 the gross margins of the retailer of cantaloupes may appear excessive. The average retailer is burdened with high overhead charges not generally appreciated by the public at large. In most cases he operates under heavy expenses, such as rent, clerical, delivery, and telephone service, the comparatively large expenditure for accounting due to the wide extension of credit, and the actual money losses which result from worthless accounts and the deterioration of the perishable products handled.

CAR-LOT, JOBBING, AND RETAIL PRICES.

In figure 5 the relation is shown between the average car-lot, jobbing, and retail prices of cantaloupes as secured over a period of 33 days in a large western market. In plotting this curve the cost to the consumer is figured per crate. It is understood, of course, that practically all sales were actually made per melon, and if the retailers had been able to sell by the crate the prices named to the consumer would have been substantially lower. These prices are not taken from published quotations but were obtained by the daily personal investigations of a member of the field force.

THE RETAILING OF CANTALOUPE.

In his position at the end of the line of agencies which distributes foodstuffs from the farm to the consumer, the retailer performs the same important functions in the marketing of cantaloupes that he



FIG. 5.—Chart showing the relation of the car-lot, jobbing, and retail prices on flat crates of Rocky Ford cantaloupes holding 15 melons in a large western market from September 7 to October 9, 1914.

does in the case of other perishable products. There is no doubt that he could increase the consumption of these highly perishable products by a change in his system of handling them and by the use of more up-to-date and efficient methods in distributing them.

Observations in the markets lead to the conclusion that the retailer could stimulate the consumption of cantaloupes by featuring them through display and attractive prices. Intelligent buying on his part and careful handling in the store, combined with the more rapid movement which would be occasioned by the lower prices, would greatly reduce his loss through deterioration. If this plan were not being followed successfully by numbers of progressive retailers, it could not be advocated with such confidence, but it repeatedly has been proved to be profitable, in spite of the handicaps under which the green grocer and fruit dealer work. The

poor quality and condition of many of the perishable products which they are forced to buy seem to be the greatest of these handicaps.

In the marketing of cantaloupes there is a good opportunity for retailers to increase their sales and reduce their losses by encouraging consumers to buy flat crates containing from 9 to 15 melons. A family of average size can easily use this number before they spoil by selecting the ripest each day and allowing the greener cantaloupes to mature. The consumer profits by getting fresh goods that have not been injured by repeated handling and at a considerable saving in cost, since the retailer can afford to work on a small margin when he sells in the original package. The retail agencies, in turn, gain by increased sales and quick turnovers, fewer poor melons returned, and reduced loss through deterioration. Instances were noticed where progressive stores employed this method and in a short time built up their trade from 2 or 3 to from 15 to 25 flat crates per day.

CANTALOUPE SHIPMENTS IN 1914.

Early in the spring of 1915 inquiries were addressed to railroad station agents at points where cantaloupes were believed to originate in carloads, asking for a complete record of the shipments during 1914. As the result of these inquiries the department has secured a fairly complete list of the points shipping cantaloupes in 1914, together with the number of carloads shipped from each. These figures have been checked to a large extent by general railroad officials of the lines on which most of the cantaloupes originate.

The map, charts, and tabulations which are the result of this inquiry should be of interest and value to the grower, the shipper, the distributor, and to all of those engaged in the handling of the cantaloupe crop.

POSSIBLE SOURCES OF ERROR.

It is very difficult to secure a complete tabulation of shipments of any perishable fruit or vegetable. This is especially true of any commodity produced in large quantities in the immediate vicinity of consuming centers. The transportation in such cases may be largely by wagon, truck, or trolley, and consequently the information if obtainable at all must be gathered from a large number of sources. In those localities where there are many shipments by boat the compilation of statistics on a carload basis is exceedingly difficult. In some cases it is probable that the tabulation here given is incomplete as to such shipments, and the figures presented were obtained by reducing crates and other packages to equivalent carloads.

EXPLANATION OF MAP.

In the map (fig. 6) showing the cantaloupe shipments in 1914 each dot represents five cars or fraction thereof. These dots are

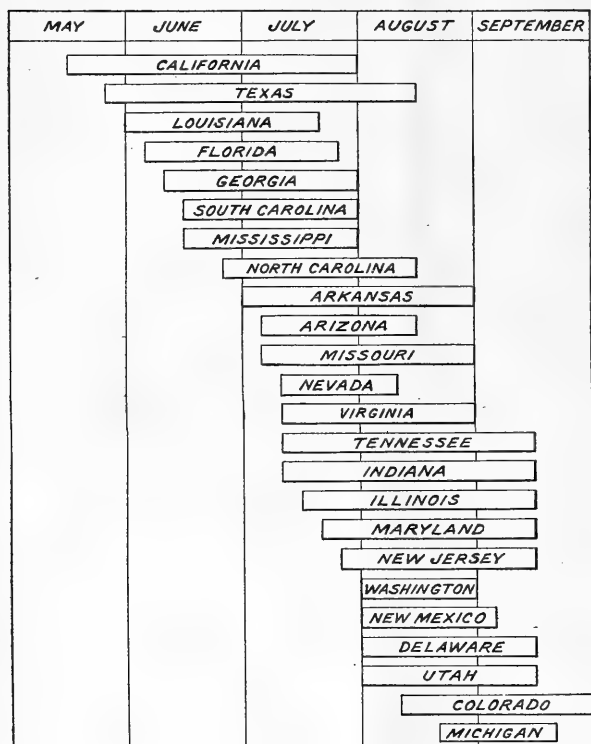


FIG. 7.—Cantaloupe shipping seasons.

county as a unit is merely for convenience and can not locate accurately the exact boundaries of producing areas.

SHIPPING DATES.

The dates within which the various areas shipped cantaloupes are shown by curved lines, all the areas shipping at a given period being grouped under the line representing that period. The first important commercial shipments of cantaloupes were from the Imperial Valley in California. These were followed closely by shipments from Florida and southern Texas, and after that the sources of supply were very widely distributed and numerous areas were in competition. These seasonal lines with their dates are subject to some changes from year to year. However, they furnish a general view of competing areas and shipping seasons which will be of value to those interested in cantaloupe marketing.

grouped in the county in which the stations are located, although it is well known that production does not actually follow county lines. In cases where the shipments are too heavy to be represented by dots, the counties have been blacked in and the actual number of cars shipped is given in figures. The size of the blackened area is not in proportion to the quantity shipped, as the tabulation plainly shows. The use of the

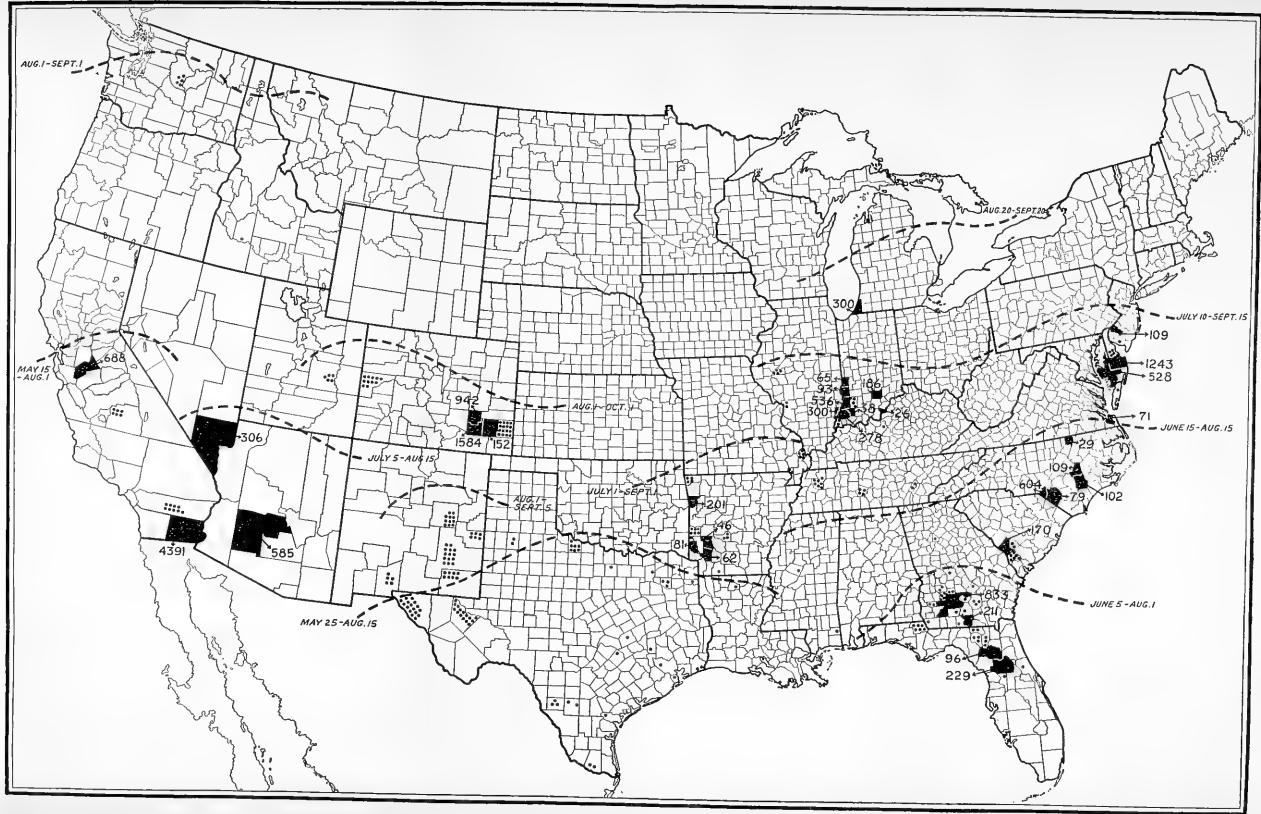


FIG. 6.—Map showing contour shipments in 1914. Each dot represents five exports for fraction three-O. The black areas represent the number of exports indicated by figures.



EXPLANATION OF CHARTS.

This same information is illustrated in the accompanying chart (fig. 7) which shows graphically how the shipping seasons of the various States may overlap. In connection with this chart it should be understood that the number of carloads shipped in the beginning of the season is often small, but increases rapidly as the season progresses, frequently reaching a maximum before the middle of the season and then gradually diminishing to its close.

The number of cars shipped from each State is also illustrated by a chart (fig. 8) which shows graphically the relative number of carloads shipped from stations in each State.

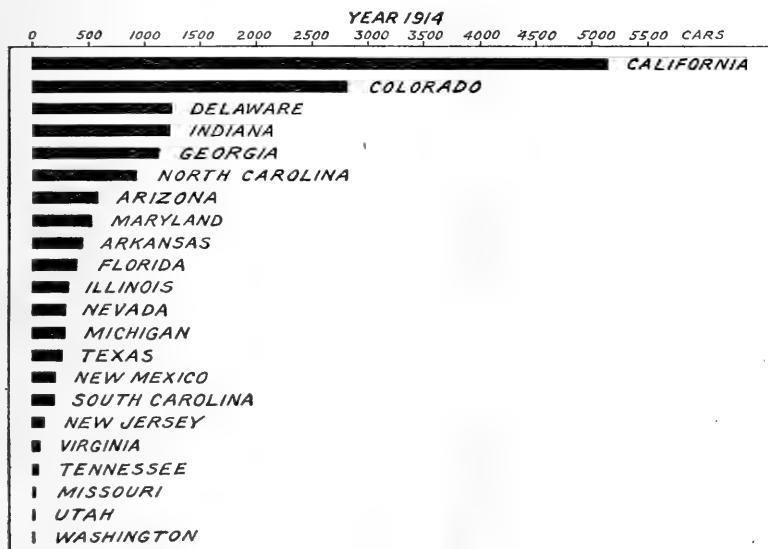


FIG. 8.—Relative bulk of cantaloupe shipments.

TABULAR STATEMENT.

The tabular statement which follows shows the cantaloupe shipping stations arranged in the order of their importance within each State, together with the actual number of cars reported shipped therefrom during the 1914 season. Seasonal variations are so great, however, that many of these figures may differ radically from the shipments usually made from those districts.

In many cases certain stations are credited in the tabulation with less-than-car-lot shipments. These stations normally ship in full carloads, but on account of some abnormal condition in 1914 they did not ship their customary quantities. Less-than-car-lot shipments have been obtained as far as possible for all stations shipping any full carloads. These shipments have been reduced to equivalent carloads and are included in the tabulation.

Cantaloupe shipments, 1914.

ARIZONA.

(July 5 to Aug. 15.)

Carloads.

Mesa.....	354
Glendale.....	231
State total.....	<u>585</u>

ARKANSAS.

(July 1 to Sept. 1.)

Van Buren.....	185
Gillham.....	41
Horatio.....	39
Delight.....	27
Blevins.....	24
Highland.....	19
Grannis.....	17
Wickes.....	14
Malvern.....	13
Gravette.....	12
Alma.....	11
McCaskill.....	11
Dotson.....	10
Deaneysville.....	7
Hope.....	6
Mulberry.....	5
Sulphur Springs.....	4
Belton.....	3
Shady Grove.....	3
De Queen.....	1
Tokio.....	1
State total.....	<u>453</u>

CALIFORNIA.

(May 15 to Aug. 1.)

Brawley.....	2,411
Heber.....	777
Keystone (Grape).....	606
Turlock.....	524
Calexico.....	438
Keyes.....	164
El Centro.....	152
Sultana.....	26
Coachella.....	21
Thermal.....	20
Imperial.....	4
Meloland.....	3
State total.....	<u>5,146</u>

COLORADO.

(Aug. 10 to Oct. 1.)

Rocky ford.....	1,008
Ordway.....	878
Swink.....	224
La Junta.....	133
Lafayette.....	108
Manzanola.....	84
Las Animas.....	80
Melonfield.....	72
Clifton.....	54
Koen.....	44
Sugar City.....	36
Holly.....	31
Olney Springs.....	28
Fowler.....	17
Cheraw.....	8
Weitzer.....	2
Bristol.....	1
Lamar.....	1
State total.....	<u>2,809</u>

DELAWARE.

(Aug. 1 to Sept. 15.)

Carloads.

Seaford.....	402
Bridgeville.....	328
Laurel.....	229
Delmar.....	170
Ross.....	53
Cannon.....	45
Houston.....	15
Oak Grove.....	9
Millsboro.....	4
Frankford.....	3
Dover.....	2
State total.....	<u>1,260</u>

FLORIDA.

(June 5 to July 25.)

Sparr.....	57
Anthony.....	54
Kendrick.....	52
Gainesville.....	47
Trenton.....	25
Grand Ridge.....	19
Fort White.....	10
Branford.....	9
Dunnellon.....	6
Oak.....	5
Ocala.....	5
Jennings.....	4
Melrose.....	4
Orangehome.....	2
DeLeon Springs.....	1
Jasper.....	1
Other stations.....	89
State total.....	<u>390</u>

GEORGIA.

(June 10 to Aug. 1.)

Camilla.....	239
Valdosta.....	188
Pelham.....	89
Sylvester.....	86
Fitzgerald.....	70
Tifton.....	59
Ashburn.....	44
Lester.....	42
Sale City.....	29
Albany.....	24
Sycamore.....	22
Poulan.....	18
Rogersville.....	16
Newsom.....	14
Baconton Station.....	12
Douglas.....	10
Spence Siding.....	10
Arabi.....	8
Maddox.....	8
Oakfield.....	7
Arlington.....	5
Sparks.....	5
Chehaw.....	4
Ellenton.....	3
Barretts.....	2
McRae.....	2
West Green.....	2
Bemiss.....	1
Fort Valley.....	1
Hopedale.....	1
Leary.....	1
Lela.....	1
Mystic.....	1
Powersville.....	1
Quitman.....	1
Stone Mountain.....	1
Perry.....	1
Other stations.....	92
State total.....	<u>1,120</u>

IDAHO.

(Aug. 10 to Sept. 15.)

Carloads.

Hammett.....	1
State total.....	<u>1</u>

ILLINOIS.

(July 15 to Sept. 15.)

Mount Carmel.....	300
Beardstown.....	18
Woodriver.....	7
State total.....	<u>325</u>

INDIANA.

(July 10 to Sept. 15.)

Decker.....	278
Purcell.....	121
Johnson.....	108
Antioch.....	100
Seymour.....	80
Terre Haute.....	65
Vollmer.....	62
Brownstown.....	60
Carlisle.....	56
Patoka.....	53
Vincennes.....	53
Vallonia.....	46
Petersburg.....	38
New Lebanon.....	37
Duncan.....	26
Oaktown.....	21
Hazleton.....	8
Mandabach.....	6
Princeton.....	6
Stewartsville.....	6
Sandy Hook.....	5
Maysville.....	4
Owensville.....	3
Cantaloupe.....	1
State total.....	<u>1,243</u>

KENTUCKY.

(Aug. 10 to Sept. 15.)

Elizabethtown.....	3
State total.....	<u>3</u>

LOUISIANA.

(June 1 to July 20.)

Choudrant.....	3
Dubach.....	1
Ruston.....	1
State total.....	<u>5</u>

MARYLAND.

(July 20 to Sept. 15.)

Salisbury.....	169
Federalsburg.....	121
Hurlock.....	112
Fruitland.....	90
Preston.....	18
East New Market.....	6
Henderson.....	6
Eden.....	4
Williamsburg.....	2
State total.....	<u>528</u>

Cantaloupe shipments, 1914—Continued.

MICHIGAN.		NEW MEXICO—Continued.		TEXAS.	
(Aug. 20 to Sept. 20.)		Carloads.		(May 25 to Aug. 15.)	
	Carloads.				Carloads.
Benton Harbor.....	270	Las Cruces.....	18	Clint.....	74
Coloma.....	20	Lakewood.....	14	Pecos.....	67
Watervliet.....	10	Mesilla Park.....	5	Vernon.....	35
State total.....	300	State total.....	212	Carrizo Springs.....	12
				Winnboro.....	11
MISSISSIPPI.		NORTH CAROLINA.		Plain View.....	10
(June 15 to Aug. 1.)		(June 25 to Aug. 15.)		Sabine Pass.....	10
Durant.....	5	Laurinburg.....	355	Cotulla.....	5
Shipman.....	1	Calypso.....	102	Fowlerton.....	5
State total.....	6	Mount Olive.....	96	Mathis.....	5
		Johns.....	93	Elgin.....	4
MISSOURI.		Hasty.....	55	Hoban.....	4
(July 5 to Sept. 1.)		Maxton.....	45	Jefferson.....	4
Morley.....	23	Omohundro Siding.....	39	Mission.....	4
Clarkton.....	6	Elmore.....	37	Verhalen.....	4
State total.....	29	Alma.....	31	Fabens.....	3
		Ridgeway.....	29	League City.....	3
NEVADA.		Covington Siding.....	16	McAllen.....	3
(July 10 to Aug. 10.)		Old Hundred.....	9	Asherton.....	2
Moapa.....	306	Goldsboro.....	7	Navasota.....	2
State total.....	306	Dudley.....	6	Addicks.....	1
		Red Springs.....	3	Alvord.....	1
NEW JERSEY.		State total.....	923	Campbell.....	1
(July 25 to Sept. 15.)				Minerva.....	1
Swedesboro.....	72	SOUTH CAROLINA.		State total.....	271
Mickleton.....	17	(June 15 to Aug. 1.)			
Woodbury.....	13	Blackville.....	131	UTAH.	
Clarksboro.....	6	Estill.....	29	(Aug. 1 to Sept. 1.)	
Harrisonville.....	1	Williston.....	20	Greenriver.....	24
Mauricetown.....	1	Ulmers.....	5	State total.....	24
State total.....	110	Govan.....	4		
		Sycamore.....	2	VIRGINIA.	
NEW MEXICO.		Other stations.....	14	(July 10 to Sept. 1.)	
(Aug. 1 to Sept. 5.)		State total.....	205	Norfolk section.....	71
Roswell.....	66	TENNESSEE.		Parksley.....	2
Fort Sumner.....	55	(July 10 to Sept. 15.)		State total.....	73
Portales.....	29	Humboldt.....	27		
Artesia.....	25	Pleasant Grove.....	17	WASHINGTON.	
		Dayton.....	7	(Aug. 1 to Sept. 1.)	
		Greenfield.....	1	Wenatchee.....	22
		State total.....	52	State total.....	22
				Grand total.....	16,401

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BULLETIN No. 316



Contribution from the Forest Service
HENRY S. GRAVES, Forester

Washington, D. C.

PROFESSIONAL PAPER

December 20, 1915

WILLOWS: THEIR GROWTH, USE, AND IMPORTANCE.

By GEORGE N. LAMB, *Forest Examiner.*

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INTRODUCTION.

There are in the United States and Canada from 80 to 100 species of willows, distributed from the Gulf of Mexico to the Arctic Circle, and from tidewater to the tops of the highest mountains. They range from a tiny plant a few inches high to forest trees 4 feet in diameter and 140 feet in height. All the shrubby species are useful as soil cover, forage, or basket material. Scarcely more than a dozen, however, are of prime economic importance. Of these, six are species imported from Europe: The basket willows, which are the American green willow (*Salix amygdalina*), the Lemley willow (*Salix pentandra*), and the purple willow (*Salix purpurea*), and three tree willows, the white willow (*Salix alba*), the crack willow (*Salix fragilis*), and the weeping willow (*Salix babylonica*). There is only one native tree species of wide distribution and importance, and this, the black willow (*Salix nigra*), is found from coast to coast and from the Lakes to the Gulf. It reaches tree size over most of this range, attaining its maximum development in the lower Mississippi bottom lands. The other native species of economic importance are *Salix amygdaloides*, *Salix cordata*, and *Salix fluviatilis*, which are primarily eastern and central species, and *Salix lasiandra*, *Salix luevigata*, *Salix lasiolepis*, and *Salix fendleriana*, the western tree willows.

THE TREE AND ITS FORMS.

The botanical name of the willow genus, *Salix*, comes from the Celtic *sal*, meaning near, and *lis*, water. The poplar is a genus of the same family. Both have more species and wider distribution in North America than on any other continent, the willows being more widely distributed than the poplars but less generally attaining tree size.

The fruit of this group is the characteristic by which it is most easily distinguished. In both genera it is a catkin an inch or more long, made up of capsules borne on a stalk and containing a cottony mass to which are attached numerous minute seeds. The catkins of the willow are smaller than those of the poplar and are generally erect; those of the poplar are generally pendant. In both cases the seed has a tuft of silky hairs attached to the base. When the capsules open the tiny seeds are borne up by the cottony hairs and carried long distances by the wind. Willow seed consists of the bare embryo or new plant and is protected by a very thin covering. It germinates in a few hours in a moist place; but if it fails to secure this condition, it loses the power of germination in two or three days.

The willows can be distinguished from the poplars by their leaves, the poplars having typically long-stalked wide leaves; the willows, short-stalked narrow ones. Willow leaves occur alternately on the branches. There are several scales on each winter bud of the poplar, but only one on each willow bud.

The willows do not normally develop a strong taproot. However, those grown on dry upland situations and some of the drought-resistant species form semitaproot systems. Usually willows grow in moist situations and places where the water table is near the surface; so the root system is shallow, spreading, and fibrous.

The bark of the different species of tree willows is very much the same, and does not furnish an obvious means of distinguishing them, except in the case of the sandbar willow, which has almost smooth bark even in trees of considerable size.

The characteristics on which botanists separate the species are largely differences in the tiny flowers and the almost microscopical variations in the leaf parts. Several species are easily identified by the size, shape, or color of the leaves, but the majority have very similar gross characteristics.

BLACK WILLOW.

(*Salix nigra* Marsh.)

The black willow is by far the most important of the native species. In the region of its best development trees have been found 4 feet in diameter at breastheight and 140 feet in height. The leaves are

long and narrow, gradually running out into a long, usually curved tip. They are thin, occasionally sickle shaped, bright green, and rather shiny. In width they vary from one-eighth to three-fourths of an inch; in length from 3 to 6 inches, being usually about 3 inches. The buds are pointed, and one-eighth of an inch long. The flowers which are borne on aments terminal on leafy branches are from 1 to 3 inches long, with short yellow scales. The bark has characteristic corky protuberances on branches from 1 to 3 years old. These are particularly abundant on vigorous sprouts grown in the open and more occasionally in dense seedling stands. The bark of old trees is from 1 inch to 1½ inches thick, occasionally 2 inches.

The black willow group is spread from Maine to central Florida and westward to central Dakota, Nebraska, and Kansas, and through Texas, New Mexico, and Arizona up to northern California. Discriminating botanists break up the group into several species.

PEACHLEAF WILLOW.

(*Salix amygdaloides* Marsh.)

The peachleaf willow ranks next to the black willow in economic importance. It reaches a height of 60 to 70 feet and a maximum diameter of 2 feet. The species is most easily distinguished from the black willow by its larger and broader leaves, generally whitish beneath. The bark is also distinctly smoother and the ridges firmer than that of the black willow. The leaves are from 3½ to 5 inches long and 1 inch wide. The buds are a dark chestnut brown, and one-eighth of an inch long. In general appearance the flowers are very similar to those of the black willow. The peachleaf willow is closely related to the black willow, and the two species hybridize freely, producing intermediate forms.

The range of the peachleaf willow is from northern New York, southwest (north of the Ohio River) through southwestern Arkansas and northern Texas, and northeast to central Washington, extending into Canada all across the continent. West of the Missouri it gradually replaces the black willow.

SANDBAR WILLOW.

(*Salix fluviatilis* Nutt.)

The sandbar, or narrow leaf, willow in its various forms is typically a shrub, found in practically the entire United States. It is particularly common on low river banks and on sand bars and new islands. A tendency to spread rapidly by root suckers makes it valuable as a soil binder. In the South Central States it has been reported as attaining a diameter of 2 feet and a height of 75 feet. This size is exceptional, and in the lower Mississippi Valley the

species is seldom over 40 feet in height and 6 inches in diameter. The narrow linear notched leaves make it easily distinguishable. They are one-eighth to one-third of an inch wide and 2 to 6 inches long. When young they are silky white, but generally become smooth at maturity. The buds and flowers resemble those of the peachleaf willow. The bark is grayish brown, and even in the large trees is scarcely furrowed. Old bark is somewhat rough.

In the mountains and on the dry plains several forms have developed which have been given separate names by botanists. From Quebec and Mackenzie to Virginia, Kentucky, Texas, and California several distinct forms have been recognized and given specific names. These variations occur principally in the western half of the United States.

DIAMOND WILLOW.

(*Salix cordata* Muhl.)

The diamond willow group has a wide distribution, and over a considerable portion of its range it occurs with great frequency. Like the sandbar willow, it has numerous forms, many of which have been given a variety of names or have been classed as separate species. Economically they can be treated as one group. The Missouri River type occasionally attains a height of 50 feet and a diameter of 18 inches, but as a rule none of the forms reaches a large size. Diamond willow is valuable chiefly for protecting stream banks and for post material. In portions of the dry prairie region diamond willow posts have been far more durable than any other native species. It is distinguished by the diamond-shaped leaf scars on the branches. The bark is also smooth and firm, somewhat similar to the sandbar willow but with more pronounced ridges. The leaves resemble the peachleaf willow at the base, but are wider in outline and more abruptly pointed. The hairy, reddish-brown winter buds, one-half inch long, also distinguish this species.

The range of the diamond willow is from New Brunswick to British Columbia, Virginia, Missouri, Colorado, and California.

WHITE WILLOW.

(*Salix alba* L.)

Of the willows imported from Europe the white willow is probably the most widely distributed in the United States. The earliest settlers brought cuttings to this country, and the species has now spread from coast to coast. It has been widely planted on the prairies and can now be found growing wild in most of the farming regions of the United States. As an individual tree it may attain a diameter of 5 to 8 feet, and when grown in stands, a height of 70 to 80 feet.

There are several forms of the white willow, one of which, the yellow willow (*Salix alba vitellina*), is as common as the white willow. The bright yellow bark of this variety and its greater inclination to branchiness readily distinguish it.

The white willow has pale-green leaves with silky pubescence on both sides, but at maturity the upper surface is nearly smooth. The edges are finely toothed. The mature leaves are from 2 to 4½ inches long and from one-third to two-fifths of an inch wide. The bark is from half an inch to 1½ inches thick on large trees, dark brown on the trunk with a reddish tinge higher up. It is deeply divided into broad, flat connecting ridges. Green, yellow, and red twigged forms are known to the trade.

CRACK WILLOW.

(*Salix fragilis* L.)

The crack willow, or gray willow, as it is often called, is quite similar in general appearance to the white willow. Under the same conditions it easily reaches the size attained by the white willow, but is in general a more slender and better formed tree. It is easily distinguished from the white willow by its larger, coarsely notched leaves and by its reddish-green twigs, which are extremely brittle at the base. The leaves are from half an inch to 1 inch wide, narrowed at the base, and from 3 to 6 inches long. At maturity they are smooth on both sides, dark green above and paler beneath. The bark is smooth and green on the upper portions of the tree. On the lower trunk it is rough, scaly, ridged, gray-brown, and 1 inch to 1½ inches thick. The crack willow does not produce so many water sprouts along the trunk as the white willow and therefore makes cleaner timber. It is undoubtedly the best willow species for plantations in the Prairie States. Many of the so-called white willow plantations are really crack willow. It is commonly planted in eastern, central, and northern United States. A yellow form is occasionally found in the nursery trade.

WEeping WILLOW.

(*Salix babylonica* L.)

The weeping willow is another of the introduced species that is now widely scattered over the United States. Though a rapid grower at first, it does not reach the size attained by the white and crack willows. The height is seldom over 50 feet, but may occasionally reach 60 feet. The diameter is often from 3 to 5 feet when the tree is grown in the open. The weeping willow can readily be distinguished from the white willow, which it most closely resembles, by

its long drooping branchlets. These are tough and pliable, but the older branches are extremely brittle.

The leaves are long, narrow, and rounded at the base, light green above and pale beneath. They closely resemble those of the black willow in shape and those of the white willow in color. When young they are somewhat silky, but are smooth when mature. They are from 4 to 7 inches long and from one-fourth to one-half inch wide. In one variety, *Salix babylonica annularis*, the leaves curl into a ring. The bark on the trunk is from three-fourths of an inch to 1½ inches thick, dark brown, becoming green or yellowish above. Besides the ring-leaved variety, a horticultural form with yellow twigs and a hairy northern variety are frequently seen.

The weeping willow is now widely planted as an ornamental tree and has frequently escaped from cultivation over practically the entire country.

PACIFIC COAST WILLOWS.

Besides the black and peachleaf willows there are five other species in the Pacific Coast States that attain tree size. None of these, however, are large enough for sawlogs and they are important chiefly for protection against erosion, although considerable quantities are available for charcoal or excelsior. This region, however, has such timber resources that it will be a long time before willow becomes as important as it is in the East. Along the coast in Oregon willows have been successfully planted as sand binders.

Four of the western willows are important. The *Salix lasiandra* (yellow willow) grows on the banks of streams throughout the coast-ranges, Sacramento to San Joaquin Valleys, and Sierra Nevada southward to southern California and northward to British Columbia. It is from 20 to 80 feet high with stout reddish twigs and brown, roughly fissured bark. The 1-year-old branches are yellowish. The leaves are from 4 to 7 inches long and from five-eighths of an inch to 1½ inches wide with a long tapering point. The *Salix laevigata* (red willow) is found along streams throughout California. It is a small tree from 20 to 40 feet high with reddish 1-year-old branchlets. The bark is firmer and lighter in color than the yellow willow. The leaves are also somewhat wider in outline. They are from 2½ to 7½ inches wide, green above and pale beneath. The *Salix lasiolepis* (arroyo willow) is commonly found along streams from Washington to California. It is a small tree from 15 to 40 feet high, easily distinguished by the almost smooth bark on the trunk. The branches are erect and have a yellowish bark. The leaves are shiny green above and whitish below, from 1½ to 5 inches long and from one-third of an inch to 1½ inches wide. The *Salix fendleriana* (Fendler's willow) grows along mountain streams from eastern Washington

and California to New Mexico. It is a tree from 30 to 60 feet in height with dark brown rough bark. The twigs are long but not slender, reddish, or reddish-yellow in color. The leaves are dark green on both sides but somewhat paler beneath, from 3 to 8 inches long and from three-fifths of an inch to $1\frac{1}{2}$ inches wide.

SOIL, MOISTURE, AND LIGHT.

Willows grow best in deep, rich, moist, alluvial bottom lands. The tree willows will grow on very poor soils, but usually as stunted trees or only large shrubs. In very sandy soils where rainfall is plentiful they grow thriftily but rather slowly. In dry soils or in soils subject to drought during a portion of the season the willows survive but grow slowly and become stag-headed at an early age. On heavy clay soils they grow moderately well if there is sufficient moisture, otherwise they survive with difficulty and seldom become trees. In good soils the willows endure a wide range of moisture conditions. Their adaptability, or rather their ability to survive, and their methods of reproduction have been responsible for their being crowded into wet places. Because they are seen so often in such places, the willows are often considered moisture-loving or swamp trees. The truth of the matter is that willows live in such places in spite of the excessive moisture conditions rather than because of them. Willows do, however, endure a period of inundation with less serious results than any but the southern swamp trees, such as cypress and water oak. They attain their best development along the lower Mississippi River, where these conditions and long growing seasons are found.

All willows are intolerant of shade. For this reason mature stands of willow are usually very open and a second-story forest exists. The black willow is slightly more tolerant than the sandbar willow and somewhat less than the peachleaf willow. Black willow is also slightly less tolerant than the cottonwood, although both are ranked as intolerant species.

SUSCEPTIBILITY TO INJURY.

INSECTS.

Willows are subject to the attack of a large number of insects, but only in exceptional seasons is the damage of a serious nature. Injury by insects is of three kinds: Defoliation, twig or shoot cutting, and bark or wood boring. The most important of these insects are fully discussed and illustrated as to appearance, habits, character of work, and remedies by Dr. F. H. Chittenden, in Bureau of Forestry Bulletin, No. 46, on pages 63-80, which may be purchased from the Superintendent of Documents, Government Printing Office. It is

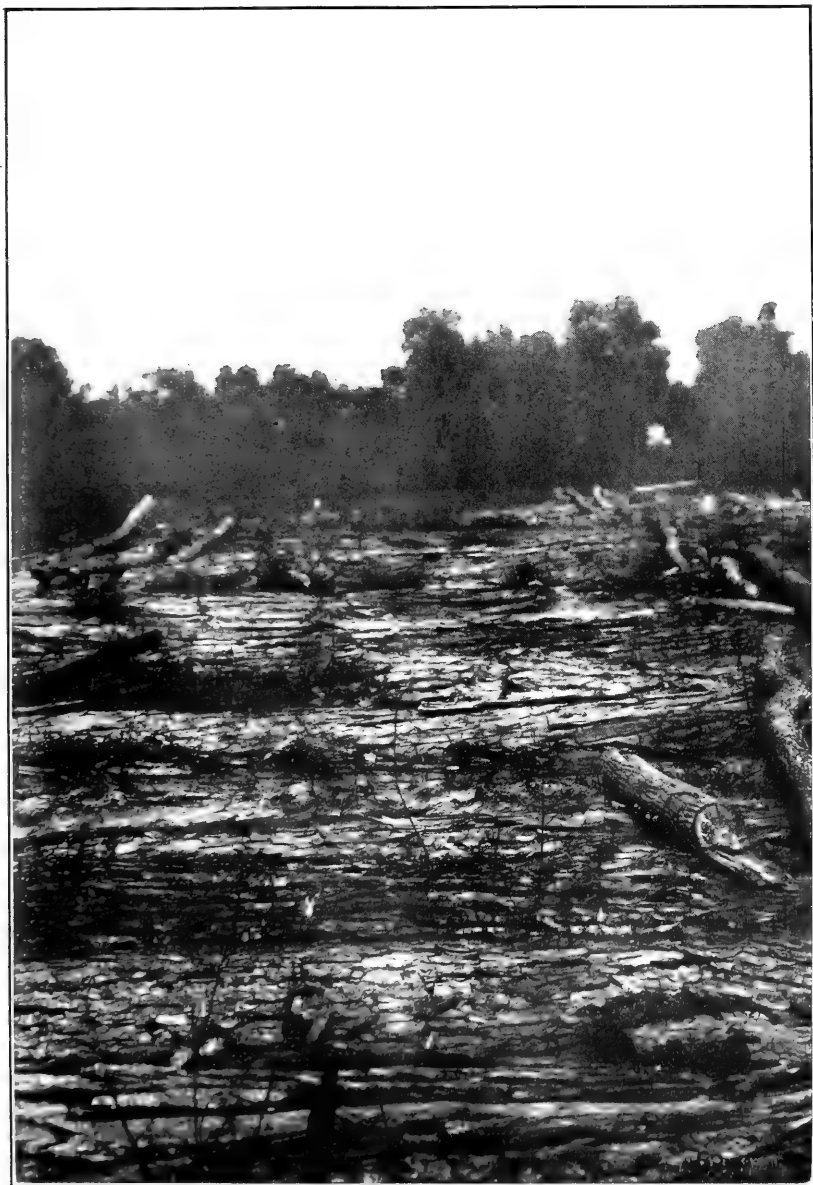
recommended, therefore, that specimens of the insects, fresh evidence of their work, and a description of the character and extent of their injury be sent to the Forest Entomologist of the Bureau of Entomology for information and advice with regard to control measures.

FUNGI.

The injury caused by the various fungi, principally defoliation and decay in the wood, is probably less than that occasioned by insects. Willows with a sufficient ornamental value to warrant the expense can be kept free from leaf diseases by spraying. Where this is done, a relatively large amount of lime, rosin, or fish-oil soap is necessary to make the spray adhere to the leaves, especially those of the smooth-leaved species, such as the laurelleaf willow. The fungi that attack the wood are of the common type, known as bracket or shelf fungi, which gain admission to the tree through injuries caused by wind, insects, and the like. Some of these grow in the living tissue and destroy sound wood, but often they simply disintegrate portions that have been deadened by other agencies. The heartwood of the willow is particularly susceptible to such attacks. The dark-red heartwood of most of the willows does not show the ravages of decay until it has far advanced, often not until the fruiting bodies appear on the surface. In the black willow stands of the South the principal fungous troubles are large "burls," commonly known as "sap knots," and heart rot. The heart rot does not necessarily occur at the base of the tree and may extend for only a short distance, the wood being sound in either direction.

WIND AND GRAZING.

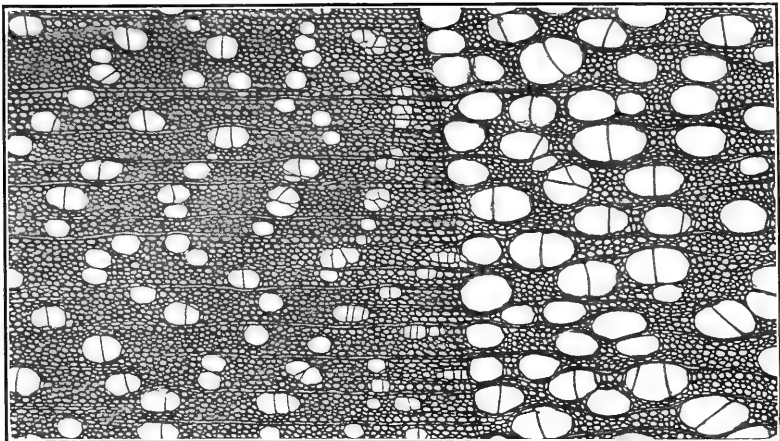
Probably the greatest enemy of the willow plantation is wind. The wide use of willows in exposed situations and the weakness of the green wood has been known to result in the almost complete demolition of individual trees and even rows of trees within 25 years after their establishment. In Iowa two rows were observed on apparently the same soil and extending in the same direction, one row exposed to the full sweep of the wind and the other protected by a cottonwood grove. Both rows were planted the same year and in the same manner. The protected row averaged 60 feet in height and only 3 per cent of the tops had been broken by the wind. In the other row 28 per cent of the trees averaged 55 feet high, and of these practically none of the tops were broken; so this height represented the normal. The other 72 per cent, however, were on an average only 40 feet high. All of these trees were more or less broken and cracked and could be saved from being completely wasted only by prompt utilization. At the age of 27 years the ex-



F-16260A

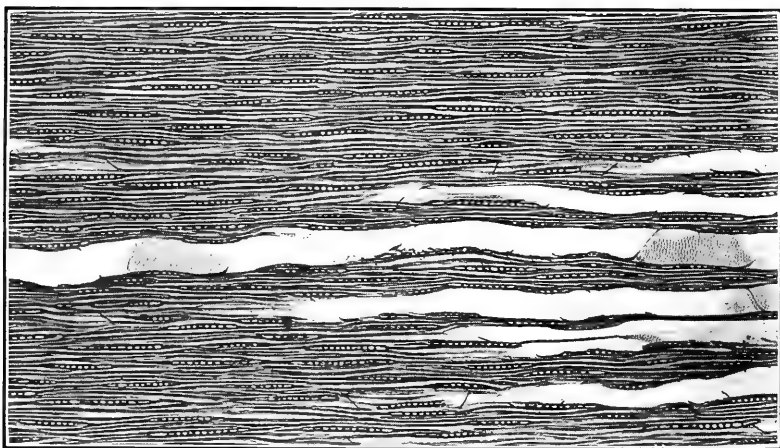
A LARGE RAFT OF BLACK WILLOW LOGS GROUND ON THE BANK OF THE YAZOO RIVER NEAR VICKSBURG, MISS.

Logs 24 feet long and from 18 inches to 36 inches in diameter at the small end.



P-3-Lab.

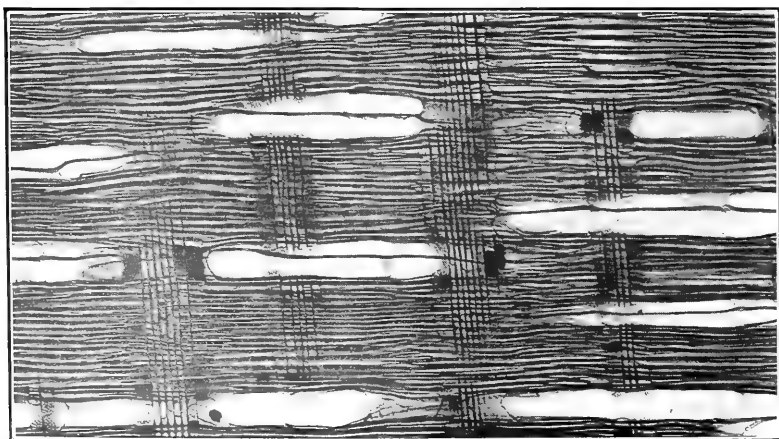
FIG. 3.—TRANSVERSE SECTION $\times 50$.



P-2-Lab.

FIG. 2.—TANGENTIAL SECTION $\times 50$.

BLACK WILLOW (*SALIX NIGRA* MARSH.).



P-1-Lab.

FIG. 1.—RADIAL SECTION $\times 50$.

posed grove was practically destroyed, while the other gave promise of unimpaired vigor for another 10 or 20 years.

In young willow plantations cattle, horses, sheep, and hogs eat the green shoots with avidity, and much damage may be done during the first 10 years of the life of the plantation. After that a small amount of browsing is often beneficial, as it clears the main stems of watershoots and small branches. Further injury by stock after this consists in barking the tree trunks, which hastens decay. The effect of grazing on the soil in the plantation is very harmful, and low yields and early decline mark the plantation where this practice is common.

FLOODS.

Willows on the flood plains of streams are more or less subject to injury during periods of high water. This has been noted as especially bad in willow plantations where the crop is pollarded, leaving a trunk from 8 to 10 feet in height. The injury to the trunk from floating débris and ice has resulted in the shortening of life, so that one or even two or three crops grown on a 7-year rotation have been lost. Such injury can be prevented by cropping at the ground and allowing the young vigorous shoots that are removed every few years to receive the blows rather than the stump, on the health of which depends the life of the pollard.

LIFE HISTORY OF THE BLACK WILLOW.

COMMERCIAL RANGE.

Of the native American species the black willow is by far the most important, on account of its wide range and its rapid growth under a variety of soil and moisture conditions. Over the greater part of its range this species is a tree willow and generally of considerable size. As a timber tree the black willow reaches its best development in the rich alluvial bottom lands of the lower Mississippi River and the lower portions of its tributaries. The quantity of merchantable black willow is much smaller than that of the cottonwood that formerly grew in this region, but to-day the cottonwood is rapidly disappearing and there is little doubt that there will soon be as much standing black willow as cottonwood between Cairo, Ill., and Baton Rouge, La. On the whole, however, it will average much lower in quality.

Most of the willow stands are found below the 35-foot stage of the river. They often occur above this mark, but are generally old trees and on being cut are replaced by cypress, gum, locust, ash, or other hardwoods. The same holds true for cottonwood to a large extent; the reproduction of old stands is very uncertain and the under story species generally takes the ground.

On the lower ground, such as small islands, old river beds, sand bars, and fills, the principal species present are black, sandbar, and peachleaf willows, and cottonwood above Cairo, Ill., the peachleaf dropping out below that point. Above Cairo the peachleaf willow divides with the black willow the position of the leading tree willow, but does not quite attain the size of the black willow or grow so rapidly. The black willow is prevalent along practically the whole course of the Mississippi, increasing in abundance and size along the lower reaches. The black willow and cottonwood are as a rule the first tree species to appear on new land.

FORM AND GROWTH OF INDIVIDUAL TREES.

Black willow trees may be divided into two general classes—that found in the North or on poor soil in the South and that of the rich alluvial river bottoms of the South. The first are typically 30 to 60 feet high and from 6 to 18 inches in diameter. They occur in pure stands over small areas or, more often, in groups of several clustered stems. In the open the black willow is a short, branchy, crooked tree, fit only for fuel. In close stands it has a moderately straight trunk or often two or three straight branches arising near the ground. The northern form, grown in close stands, can be utilized for fuel, charcoal, excelsior, or pulp, and occasionally for artificial limbs, but seldom develops into a desirable sawlog. The southern type is considerably different in habit of growth in the forest. The trunks are usually separate and stand quite erect. In the open the tree branches, like the northern form, being different only in its larger size. The forest-grown tree has a minimum clear length of 20 feet and an average clear length of about 40 feet, and, as a maximum, several specimens have been measured having over 80 feet of clear, straight bole. The tops of these trees are small, irregular, and often broken. The crowns are narrow, open, and deep. The average diameter in mature stands is about 18 inches at the mouth of the Ohio and increases to 24 inches in Mississippi and Louisiana. The largest breast-high diameter measurement recorded for a forest-grown black willow is 44 inches and the greatest height 140 feet. The tree with the greatest height measurement, however, was not the one with the greatest diameter growth. The 44-inch tree was not over 125 feet high and the 140-foot tree was not over 3 feet in diameter. The average height in mature stands at the mouth of the Ohio is approximately 85 feet; in Louisiana it ranges from 100 to 120 feet. Black willow is a short-lived tree. The greatest age recorded for a sound tree is 70 years; the greatest age recorded for a living but unsound tree is 85 years. The average age at which stands mature is 55 years and under favorable conditions may be 10 years less.

The bark of the forest-grown black willow varies considerably. On trees 2 feet or more in diameter it is usually 1.2 to 1.5 inches thick at stump height, as measured by the caliper or diameter tape. Typically it is rather soft and easily broken and sometimes hangs in loose flat scales. Occasionally it is very hard, the ridges being, therefore, deep.

The black willow has no pronounced taproot, although there may be several smaller roots extending downward beneath the trunk of the tree. On well-drained soils it develops a lateral root system, and on poorly drained soils where the water table is habitually near the surface of the ground the root system is decidedly lateral, uprooted trees often showing a depth of root of less than a foot.

TYPES AND ASSOCIATED SPECIES.

Practically all black willow stands have originated along the low banks of streams or lakes or have gained a foothold on areas which have received a generous deposit of sediment. The pure stands are usually on the lowest land or first bottoms. On the higher ground the willows are found to be mixed more and more with other species; in the North, principally elm, maple, ash, cottonwood, and boxelder, and in the South, cottonwood, with small amounts of ash, maple, sycamore, or cypress. The southern black willow stands must be considered temporary. Most of the land on which they are found is accretion land. Along the Mississippi the willow lands extend ordinarily from the water level to 35 feet above it, although the drainage conditions are more important in deciding this than the actual height of the land. In the extreme South, where there is a much larger area of bottom land than in the North, poor drainage results in the appearance of such species as cypress, water oak, and red gum in places where, with better drainage, cottonwood and willow would have been the first stand. The willow stand, whether it be along the rivers or in prairie plantations, must always be considered an advance guard or pioneer stand. As soon as soil or economic conditions improve it is generally replaced by other species.

GROWTH OF BLACK WILLOW.

HEIGHT GROWTH.

Black willow grows very rapidly in height, not only because of its inherent vigor but also as a result of the intense competition for light which is caused by its intolerance and the density of the stands in which it naturally comes up. Both the annual growth and the total height attained by the mature tree are greater in the South than in the North. Table 1 shows the average height of stands of approximately the same age at different points in the Mississippi Valley.

TABLE 1.—Average height of willow stands in the Mississippi Valley.

Stand near—	Age.	Stand.	Soil.	Average height.
	<i>Years.</i>			<i>Feet.</i>
Clay City, Ind.....	53	Close.....	Sandy.....	82
Ste. Genevieve, Mo.....	40	Medium.....	do.....	74
Cairo, Ill.....	42	Close.....	do.....	83
Memphis, Tenn.....	37	Medium.....	Very poor drainage.....	81
Helena, Ark.....	55	Close.....	Black.....	110
Vicksburg, Miss.....	41	do.....	do.....	98
St. Joseph, La.....	45	do.....	do.....	116
Williamsport, La.....	57	do.....	do.....	104

In the South black willow attains its principal height growth at from 35 to 40 years; in the North at from 30 to 35 years. In the South, however, growth frequently continues more slowly after this age until the heights ranging between 100 and 135 feet are reached. Table 2 gives the average height growth of black willow, based on 255 trees in the Mississippi Valley region from southern Indiana and southern Missouri to central Louisiana. Most of these measurements were taken in the southern half of this range.

TABLE 2.—Height growth of black willow in the Mississippi Valley.

(Based on 255 trees.)

Age.	Height.	Growth in 5-year periods.	Periodic annual growth.	Age.	Height.	Growth in 5-year periods.	Periodic annual growth.
<i>Years.</i>	<i>Feet.</i>	<i>Feet.</i>	<i>Feet.</i>	<i>Years.</i>	<i>Feet.</i>	<i>Feet.</i>	<i>Feet.</i>
5	32	32	6.4	35	96	7	1.4
10	50	18	3.6	40	101	5	1.0
15	63	13	2.6	45	105	4	.8
20	73	10	2.0	50	109	4	.8
25	82	9	1.8	55	113	4	.8
30	89	7	1.4	60	116	3	.6

DIAMETER GROWTH.

Black willow makes its most rapid diameter growth during the first 10 years, after which the growth falls off gradually. At the age of 60 years the average tree is generally mature or overmature, and produces little increment after that. Occasionally an individual will survive longer than this in a protected place and continue growing up to an age of 75 years. On poor sites, such as a rather sandy river bank, or on soils having a scant moisture supply, the diameter growth is about 0.4 of an inch per year for the first 10 years, while on the best sites in the South, where there is a long growing season, it averages from 0.5 to 0.7 of an inch. The maximum annual diameter growth on the best sites is 0.9 of an inch the first 10 years. A particularly interesting fact is noted in that beyond the age of 45 years the annual diameter growth of all trees is practically the same, averaging about 0.28 of an inch. The trees having a maximum

diameter growth gain their lead over the average trees during the first two decades. By thinning, the diameter growth can be made more sustained.

Table 3 is based on measurements of 34 trees in Arkansas with stumps 2.5 to 3.2 feet in diameter and 42 to 63 years old. Soil, a rich, moist bottom land. The trees when plotted were divided into three classes based on diameter growth. The minimum growth given in the table is the average for the slowest growing trees; the average growth is for the trees growing at a medium rate and the maximum growth is an average for the fastest growing trees. Neither the minimum nor the maximum growth is the slowest or fastest found for individual trees.

TABLE 3.—*Diameter growth of black willow, Phillips County, Ark.*

Age.	Diameter, breasthigh.			Increase in diameter by 5-year periods.		
	Minimum.	Average.	Maximum.	Minimum.	Average.	Maximum.
<i>Years.</i>	<i>Inches.</i>	<i>Inches.</i>	<i>Inches.</i>	<i>Inches.</i>	<i>Inches.</i>	<i>Inches.</i>
5	1.4	2.6	3.9	1.4	2.6	3.9
10	3.3	5.6	7.9	1.9	3.0	4.0
15	5.3	8.5	11.4	2.0	2.9	3.5
20	7.5	11.1	14.4	2.2	2.6	3.0
25	9.5	13.5	17.3	2.0	2.4	2.9
30	11.5	15.6	19.8	2.0	2.1	2.5
35	13.3	17.5	22.1	1.8	1.9	2.3
40	15.1	19.4	24.3	1.8	1.9	2.2
45	16.6	21.2	26.3	1.5	1.8	2.0
50	18.1	22.8	28.2	1.5	1.6	1.9
55	19.6	24.3	29.9	1.5	1.5	1.7
60	21.0	25.7	31.6	1.4	1.4	1.7

Table 4 is based on measurements of 76 trees in Mississippi with stumps 16 to 34.6 inches in diameter inside bark and 36 to 58 years old. Soil, a rich, moist bottom land.

TABLE 4.—*Diameter growth of black willow, Jefferson County, Miss.*

Age.	Diameter, breasthigh.			Increase in diameter by 5-year periods.		
	Minimum.	Average.	Maximum.	Minimum.	Average.	Maximum.
<i>Years.</i>	<i>Inches.</i>	<i>Inches.</i>	<i>Inches.</i>	<i>Inches.</i>	<i>Inches.</i>	<i>Inches.</i>
5	1.9	3.1	4.9	1.9	3.1	4.9
10	3.9	6.5	9.0	2.0	3.4	4.1
15	5.9	9.5	12.6	2.0	3.0	3.6
20	7.5	12.2	15.9	1.8	2.7	3.3
25	9.0	14.4	18.7	1.5	2.2	2.8
30	10.4	16.2	21.4	1.4	1.8	2.7
35	11.7	17.9	23.8	1.3	1.7	2.4
40	13.0	19.3	26.0	1.3	1.4	2.2
45	14.2	20.8	27.8	1.2	1.5	1.8
50	15.4	22.2	29.3	1.2	1.4	1.5
55	16.7	23.5	30.7	1.3	1.3	1.4
60	17.7	24.7	31.8	1.0	1.2	1.1

VOLUME IN BOARD MEASURE.

The following tables are based on taper tables constructed from measurements of 256 selected trees, taken principally in Arkansas, Mississippi, and Louisiana, with a few in Missouri and Indiana. All measurements were taken on trees less than 60 years old, growing on rich alluvial bottom lands. Practically all the trees measured were felled in logging operations. The figures in heavy-faced type indicate the volumes of trees of average heights. Table 5 shows the volume based on diameters breasthigh from 14 to 36 inches, and heights 10 feet apart from 60 to 130 feet. The top diameter limit runs from 10 inches in the 14-inch trees to 26 inches in the 36-inch trees, giving very incomplete utilization. Table 6 shows the volume based on diameters breasthigh and number of 16-foot logs per tree.¹ The trees forming the basis of both tables were scaled with the Scribner Decimal C rule.

TABLE 5.—*Black willow—Mississippi Valley.*

Diameter breast-high.	Total height of tree—feet.								Diameter inside bark of top.	Basis.
	60	70	80	90	100	110	120	130		
	Volume—board feet.									
<i>Inches.</i>	60	90	120	150	160				<i>Inches.</i>	<i>Trees.</i>
14	70	100	140	170	190				10	
15									11	2
16	80	120	160	190	210				12	3
17	90	140	180	210	240				12	11
18	100	160	200	240	270	280			13	9
19		180	220	270	300	320			14	6
20		200	250	300	330	360	370		14	12
21		220	280	340	370	400	410		15	23
22		250	320	370	410	440	460	480	16	25
23		270	350	410	450	490	510	540	17	23
24		300	390	450	490	530	560	590	17	23
25			430	490	540	580	620	650	18	15
26			470	530	590	630	670	700	19	15
27			520	580	630	680	730	760	19	16
28			570	630	680	730	780	820	20	9
29			620	680	740	790	840	880	21	7
30			670	730	790	840	900	940	22	8
31				780	840	900	950	1,000	22	8
32				830	890	950	1,010	1,070	23	3
33				880	950	1,000	1,070	1,130	24	6
34				930	1,000	1,060	1,130	1,190	24	3
35				990	1,050	1,120	1,190	1,260	25	1
36				1,040	1,100	1,170	1,250	1,320	26	1
										229

¹ Scaled from taper curves mostly in 16.3-foot logs with a few shorter logs where necessary. Stump height, 1 foot.

TABLE 6.—*Black willow—Mississippi Valley.*

Diameter breast-high.	Number of 16-foot logs.					Diameter inside bark of top.	Basis.
	1	1½	2	2½	3		
	Volume—board feet.						
Inches.						Inches.	Trees.
14	62	97	130	170	-----	10	-----
15	72	120	160	200	-----	11	2
16	83	140	180	230	-----	12	3
17	96	160	210	260	-----	12	11
18	110	180	250	300	-----	13	9
19	130	210	280	350	-----	14	6
20	140	240	320	390	-----	14	12
21	160	260	350	440	-----	15	23
22	180	290	390	490	-----	16	25
23	210	320	430	540	-----	17	23
24	230	350	470	600	730	17	23
25	250	380	520	660	810	18	15
26	280	410	560	730	890	19	15
27	-----	440	610	800	980	19	16
28	-----	480	670	870	1,070	20	9
29	-----	510	720	940	1,160	21	7
30	-----	550	780	1,020	1,260	22	8
31	-----	590	840	1,100	1,360	22	8
32	-----	630	900	1,180	1,460	23	3
33	-----	670	960	1,260	1,570	24	6
34	-----	700	1,020	1,340	1,670	24	3
35	-----	740	1,080	1,430	1,780	25	1
36	-----	780	1,140	1,510	1,880	26	1

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Tables 7 and 8 are similar to Tables 5 and 6 except that the trees were scaled with the Doyle instead of the Scribner Decimal C rule.

TABLE 7.—*Black willow—Mississippi Valley.*

Diam- eter breast- high.	Total height of tree—feet.								Diam- eter inside bark of top.	Basis.
	60	70	80	90	100	110	120	130		
	Volume—board feet.									
<i>Inches.</i>									<i>Inches.</i>	<i>Trees.</i>
14	52	64	82	100	130	140			10	
15	60	80	100	120	150	160			11	2
16	68	97	120	150	170	180	190		12	3
17	73	110	150	170	190	210	220		12	11
18	79	130	170	200	220	240	250	270	13	9
19		150	200	230	250	270	290	310	14	6
20		180	230	270	290	310	330	350	14	12
21		200	260	300	330	360	370	390	15	23
22		230	290	340	370	400	420	440	16	25
23		260	330	380	410	450	470	490	17	23
24		290	360	420	460	500	520	540	17	23
25			400	470	510	550	570	600	18	15
26			450	510	560	600	620	660	19	15
27			490	560	610	650	680	710	19	16
28			540	610	660	710	740	770	20	9
29			590	660	720	760	800	840	21	7
30			650	710	770	820	860	900	22	8
31				760	820	880	920	970	22	8
32				810	870	940	990	1,040	23	3
33				860	920	1,000	1,050	1,100	24	6
34				920	980	1,060	1,120	1,170	24	3
35				970	1,030	1,120	1,190	1,240	25	1
36				1,020	1,090	1,180	1,250	1,310	26	1
										220

TABLE 8.—*Black willow—Mississippi Valley.*

Diam- eter breast- high.	Number of 16-foot logs.					Diam- eter inside bark of top.	Basis.
	1	1½	2	2½	3		
	Volume—board feet.						
<i>Inches.</i>						<i>Inches.</i>	<i>Trees.</i>
14	40	69	100	130	-----	10	-----
15	51	89	120	160	-----	11	2
16	64	110	150	190	-----	12	3
17	78	130	180	230	-----	12	11
18	94	160	210	270	-----	13	9
19	110	180	240	310	-----	14	6
20	130	210	280	350	430	14	12
21	150	230	320	400	490	15	23
22	170	260	360	450	550	16	25
23	200	290	400	500	610	17	23
24	220	320	440	560	680	17	23
25	240	360	490	620	750	18	15
26	270	390	530	680	830	19	15
27	-----	420	580	740	910	19	16
28	-----	460	640	810	1,000	20	9
29	-----	500	690	890	1,090	21	7
30	-----	530	750	970	1,190	22	8
31	-----	570	810	1,050	1,290	22	8
32	-----	600	870	1,140	1,400	23	3
33	-----	640	940	1,240	1,520	24	6
34	-----	670	1,000	1,330	1,640	24	3
35	-----	710	1,070	1,430	1,770	25	1
36	-----	750	1,140	1,530	1,900	26	1
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Tables 9 and 10 are similar to Tables 5 and 6, respectively, except in regard to closeness of utilization. Table 9 shows the volume based on diameters breasthigh from 8 to 36 inches and height classes 10 feet apart, from 60 to 130 feet, and also the average height of trees of different diameters. The top diameter limit is from 6 inches for the 8-inch trees up to 16 inches for the 36-inch trees. The volumes of trees of average heights are shown in heavy-faced type. Table 10 shows the volume based on diameters breasthigh from 8 to 36 inches and the number of 16-foot logs per tree, scaled from taper curves, mostly in 16.3-foot logs, with a few shorter lengths where necessary. The stump height is 1 foot. The trees on which both tables are based were scaled with the Scribner Decimal C rule and the tables show what could be taken from them by close utilization.

TABLE 9.—*Black willow—Mississippi Valley.*

Diam- eter breast- high.	Total height of tree—feet.								Average height.	Diam- eter inside bark of top.	Basis.
	60	70	80	90	100	110	120	130			
	Volume—board feet.										
<i>Inches.</i>									<i>Feet.</i>	<i>Inches.</i>	<i>Trees.</i>
8	19	30	43	57	-----	-----	-----	-----	58	6	11
9	26	42	55	71	-----	-----	-----	-----	65	6	5
10	36	56	70	90	-----	-----	-----	-----	71	6	5
11	47	70	89	110	-----	-----	-----	-----	76	6	2
12	59	86	110	140	170	-----	-----	-----	81	6	-----
13	72	100	140	170	200	-----	-----	-----	86	6	-----
14	89	130	160	200	230	250	-----	-----	90	6	-----
15	110	150	190	230	270	290	-----	-----	93	6	2
16	120	170	220	270	300	330	350	-----	96	6	3
17	140	200	250	300	340	380	400	-----	98	6	11
18	160	230	290	340	390	430	460	490	100	6	9
19	-----	260	320	380	440	480	520	560	101	6	6
20	-----	290	360	430	490	540	580	630	103	6	12
21	-----	320	400	480	550	600	650	700	104	7	23
22	-----	360	450	540	610	670	720	780	105	7	25
23	-----	400	500	600	670	740	800	860	106	8	23
24	-----	440	550	660	740	810	880	940	107	8	23
25	-----	-----	620	730	810	890	960	1,020	108	9	15
26	-----	-----	690	800	890	970	1,050	1,110	109	10	15
27	-----	-----	770	880	970	1,060	1,140	1,200	109	10	16
28	-----	-----	860	960	1,060	1,150	1,230	1,300	110	11	9
29	-----	-----	-----	1,040	1,140	1,240	1,330	1,400	110	11	7
30	-----	-----	-----	1,130	1,230	1,330	1,430	1,510	111	12	8
31	-----	-----	-----	1,210	1,320	1,430	1,530	1,630	111	13	8
32	-----	-----	-----	1,290	1,420	1,530	1,640	1,740	112	13	3
33	-----	-----	-----	1,380	1,510	1,630	1,750	1,860	112	14	6
34	-----	-----	-----	1,460	1,600	1,740	1,860	1,980	113	14	3
35	-----	-----	-----	1,550	1,700	1,840	1,970	2,100	113	15	1
36	-----	-----	-----	1,630	1,790	1,950	2,090	2,220	113	16	1
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TABLE 10.—*Black willow—Mississippi Valley.*

Diam- eter breast- high.	Number of 16-foot logs.											Diam- eter inside bark of top.	Basis.
	2	2½	3	3½	4	4½	5	5½	6	6½	7		
	Volume—board feet.												
<i>Inches.</i>												<i>Inches.</i>	<i>Trees.</i>
8	38	52	64	-----	-----	-----	-----	-----	-----	-----	-----	6	11
9	41	56	70	-----	-----	-----	-----	-----	-----	-----	-----	6	5
10	46	61	78	90	-----	-----	-----	-----	-----	-----	-----	6	5
11	51	68	87	100	-----	-----	-----	-----	-----	-----	-----	6	2
12	58	76	99	120	150	170	200	-----	-----	-----	-----	6	-----
13	66	87	110	130	160	190	220	-----	-----	-----	-----	6	-----
14	76	98	130	150	180	210	240	270	300	-----	-----	6	-----
15	85	110	140	170	210	240	270	300	330	-----	-----	6	2
16	97	130	160	190	230	270	300	340	370	400	-----	6	3
17	-----	140	180	220	260	300	340	380	410	450	-----	6	11
18	-----	160	200	240	290	330	380	420	460	500	540	6	9
19	-----	-----	220	270	320	370	420	470	520	560	610	6	6
20	-----	-----	240	300	360	420	470	530	580	630	680	6	12
21	-----	-----	270	340	410	470	530	590	650	700	750	7	23
22	-----	-----	300	380	460	530	600	670	730	790	840	7	25
23	-----	-----	340	430	510	600	670	750	820	880	940	8	23
24	-----	-----	380	480	570	670	750	830	910	980	1,040	8	23
25	-----	-----	-----	540	640	740	830	920	1,000	1,070	1,150	9	15
26	-----	-----	-----	610	710	830	920	1,010	1,100	1,180	1,270	10	15
27	-----	-----	-----	690	790	910	1,010	1,110	1,200	1,290	1,390	10	16
28	-----	-----	-----	780	870	1,000	1,110	1,210	1,310	1,410	1,510	11	9
29	-----	-----	-----	-----	960	1,090	1,210	1,320	1,430	1,530	1,640	11	7
30	-----	-----	-----	-----	1,040	1,180	1,310	1,440	1,560	1,680	1,790	12	8
31	-----	-----	-----	-----	1,120	1,280	1,420	1,560	1,690	1,830	1,940	13	8
32	-----	-----	-----	-----	1,210	1,370	1,530	1,690	1,840	2,000	2,110	13	3
33	-----	-----	-----	-----	1,300	1,470	1,640	1,820	1,990	2,170	2,300	14	6
34	-----	-----	-----	-----	1,390	1,560	1,760	1,950	2,130	2,330	2,490	14	3
35	-----	-----	-----	-----	1,480	1,660	1,870	2,090	2,280	2,500	2,690	15	1
36	-----	-----	-----	-----	1,570	1,760	1,990	2,220	2,430	2,670	2,890	16	1
													252

VOLUME IN CUBIC FEET.

Table 11 gives in cubic feet the total volume, including bark, of trees from 5 to 44 inches in diameter, and from 40 to 140 feet high. The table is based on measurements of 256 trees, taken mostly in Arkansas, Mississippi, and Louisiana, with a few in Missouri and Indiana. The volumes of trees of average height are shown in heavy-faced type.

TABLE 11.—*Black willow—Mississippi Valley.*

Dia- meter breast- high.	Total height of tree—feet.											Basis.
	40	50	60	70	80	90	100	110	120	130	140	
	Total volume of stem, including bark—cubic feet.											
<i>Inches.</i>												<i>Trees.</i>
5	2.8	3.5	4.3	5.0	-----	-----	-----	-----	-----	-----	-----	1
6	4.1	5.1	6.1	7.1	-----	-----	-----	-----	-----	-----	-----	7
7	5.6	6.9	8.3	9.7	10.9	-----	-----	-----	-----	-----	-----	7
8	7.3	9.1	10.9	12.7	14.2	-----	-----	-----	-----	-----	-----	6
9	9.2	11.5	13.8	16.1	18.0	20	-----	-----	-----	-----	-----	7
10	11.3	14.2	17.0	19.9	22	25	-----	-----	-----	-----	-----	5
11	13.7	17.2	21	24	27	30	32	-----	-----	-----	-----	2
12	16.3	20	25	29	32	35	38	-----	-----	-----	-----	-----
13	-----	24	29	34	38	41	45	49	-----	-----	-----	-----
14	-----	28	33	39	44	48	52	56	-----	-----	-----	-----
15	-----	32	38	45	50	55	60	65	69	-----	-----	2
16	-----	36	44	51	57	63	68	74	79	-----	-----	3
17	-----	49	57	64	71	77	83	89	92	-----	-----	11
18	-----	55	64	72	80	87	93	100	103	-----	-----	9
19	-----	61	72	80	89	96	104	111	115	119	-----	6
20	-----	68	79	89	98	107	115	123	128	131	-----	12
21	-----	-----	88	98	108	118	127	136	141	145	-----	22
22	-----	-----	96	108	119	129	139	149	154	159	-----	23
23	-----	-----	105	118	130	141	152	163	169	174	-----	23
24	-----	-----	114	128	141	154	166	177	184	189	-----	24
25	-----	-----	-----	139	153	167	180	192	199	205	-----	15
26	-----	-----	-----	150	166	181	195	208	216	222	-----	14
27	-----	-----	-----	162	179	195	210	224	233	239	-----	15
28	-----	-----	-----	174	192	210	226	241	250	257	-----	9
29	-----	-----	-----	-----	206	225	242	259	268	276	-----	9
30	-----	-----	-----	-----	221	241	259	277	287	296	-----	8
31	-----	-----	-----	-----	236	257	277	296	307	316	-----	8
32	-----	-----	-----	-----	251	274	295	315	327	336	-----	3
33	-----	-----	-----	-----	267	291	314	335	348	358	-----	6
34	-----	-----	-----	-----	284	309	333	356	369	380	-----	3
35	-----	-----	-----	-----	-----	327	353	377	391	402	-----	1
36	-----	-----	-----	-----	-----	346	373	399	414	426	-----	1
37	-----	-----	-----	-----	-----	366	394	421	437	449	-----	-----
38	-----	-----	-----	-----	-----	386	416	444	461	474	-----	-----
39	-----	-----	-----	-----	-----	406	438	468	485	499	-----	-----
40	-----	-----	-----	-----	-----	428	461	492	511	525	-----	-----
41	-----	-----	-----	-----	-----	-----	484	517	536	552	-----	-----
42	-----	-----	-----	-----	-----	-----	508	543	563	579	-----	-----
43	-----	-----	-----	-----	-----	-----	532	569	590	607	-----	-----
44	-----	-----	-----	-----	-----	-----	558	596	618	636	-----	1
												256

SOLID CONTENT OF CORDS.

The solid content in cubic feet of stacked cords made up of trees of different diameters can be ascertained by referring to the following table. The solid content of trees from 1 to 5 inches in diameter such as furnish the brush used in revetment work, for which the whole tree is taken, was computed from the average weight of a cord of brush as compared with the weight of a cord of excelsior wood. The remainder of the table was computed from measurements taken in Indiana where excelsior wood was being cut in the woods from trees 3 to 12 inches in diameter, from measurements taken in Louisiana, and from wood being bolted for staves.

TABLE 12.—*Solid content in cubic feet of stacked cords from trees of different sizes.*

Diameter of trees.	Solid con- tent of a cord.
<i>Inches.</i>	<i>Cubic feet.</i>
¹ Brush...	53
3 to 10...	75
10 to 15...	88
15 to 20...	91
20 to 25...	93
25 to 30...	94

¹Used in revetment work along Mississippi River; includes trees from 1 to 5 inches in diameter.

IMPORTANCE OF CLOSE UTILIZATION.

Table 13 gives, for average trees, loss in board feet and percentage of loss through imperfect utilization. Column 2 shows the average height of trees of different diameters. Column 3 is the cubic-foot content for trees of this size as given in Table 11. Column 4 is the board-foot content of the same trees as given in Table 5, showing wasteful utilization. Column 5 is the board-foot content of the same trees taken from Table 9, showing close utilization. Column 6 is the difference between wasteful and close utilization in board feet, and column 7 gives the percentage of loss in board feet resulting from imperfect utilization. The difference runs from 25 per cent in the 14-inch trees to 40 per cent in the 36-inch trees.

TABLE 13.—*The loss in board feet of the willow timber left in the woods.*

Diameter.	Height.	Cubic content.	Volume.			Per cent of loss.
			Close utilization.	Wasteful utilization.	Loss.	
<i>Inches.</i>	<i>Feet.</i>	<i>Cubic feet.</i>	<i>Board feet.</i>	<i>Board feet.</i>	<i>Board feet.</i>	
8	58	10.9	19		19	-----
9	65	16.1	42		42	-----
10	71	19.9	56		56	-----
11	76	27	89		89	-----
12	81	32	110		110	-----
13	86	41	170		170	-----
14	90	48	200	150	50	25.0
15	93	55	230	170	60	26.1
16	96	68	300	210	90	30.0
17	98	77	340	240	100	29.4
18	100	87	390	270	120	30.8
19	101	96	440	300	140	31.8
20	103	107	490	330	160	32.7
21	104	118	550	370	180	32.7
22	105	139	670	440	230	34.3
23	106	152	740	490	250	33.8
24	107	166	810	530	280	34.6
25	108	180	890	580	310	34.8
26	109	195	970	630	340	35.1
27	109	210	1,060	680	380	35.8
28	110	226	1,150	730	420	36.5
29	110	242	1,240	790	450	36.3
30	111	259	1,330	840	490	36.8
31	111	277	1,430	900	530	37.1
32	112	295	1,530	950	580	37.9
33	112	314	1,630	1,000	630	38.7
34	113	333	1,740	1,060	680	39.1
35	113	353	1,840	1,120	720	39.1
36	113	373	1,950	1,170	780	40.0

FORM TABLES.

The foregoing volume tables were made by scaling the average tree in each diameter and height class, and are intended to show the volume of the trees according to the log scales most commonly used both under the present system of utilization and under a closer system. In each case, however, the diameter limit established is an arbitrary matter and the volume shown applies only for the particular log scale used. In the following form tables the actual average taper measurements are given, and from these it is possible to construct volume tables for any log scale and any degree of utilization. Moreover, tables can be constructed to show the contents of the trees not only in board feet but in any other unit, such as cordwood, posts, etc., that may be desired. In the form tables are shown diameter classes from 8 inches to 36 inches at intervals of 1 inch and height classes from 60 to 130 feet at intervals of 10 feet. The heights above ground represent 16.3-foot logs and half logs plus a stump height of 1 foot. The tables are based on the measurement of 252 trees in Indiana, Arkansas, Missouri, Louisiana, and Mississippi.

TABLE 14.—*Diameters inside bark at different heights above the ground for trees of different sizes, based on measurements of 252 trees in Indiana, Arkansas, Missouri, Mississippi, and Louisiana.*

(The heights above ground represent 16.3-foot logs and half logs, plus a stump height of 1 foot.)

Diameter breasthigh.	60-FOOT TREES.						70-FOOT TREES.							
	Height above ground—feet.													
	4.5	9.15	17.3	25.45	33.6	41.75	4.5	9.15	17.3	25.45	33.6	41.75	49.9	58.05
Inches.	Diameter inside bark—inches.													
8.....	7.4	6.8	6.0	5.1	4.0	2.8	7.4	6.9	6.2	5.5	4.8	3.8	2.8	1.8
9.....	8.3	7.7	6.7	5.7	4.6	3.2	8.3	7.8	7.0	6.3	5.5	4.4	3.3	2.1
10.....	9.2	8.6	7.4	6.2	4.9	3.5	9.2	8.7	7.8	7.0	6.0	4.9	3.8	2.4
11.....	10.1	9.5	8.3	6.9	5.5	3.9	10.1	9.5	8.6	7.7	6.6	5.4	4.2	2.7
12.....	11.0	10.4	9.0	7.5	5.9	4.2	11.0	10.4	9.4	8.4	7.2	6.0	4.6	3.0
13.....	11.9	11.3	9.8	8.2	6.5	4.6	11.9	11.3	10.2	9.2	7.9	6.5	5.0	3.4
14.....	12.9	12.1	10.5	8.8	6.8	4.9	12.9	12.1	11.0	9.8	8.5	7.0	5.5	3.7
15.....	13.8	13.0	11.4	9.4	7.4	5.4	13.8	13.0	11.8	10.6	9.2	7.6	5.9	4.0
16.....	14.8	13.9	12.0	10.0	7.9	5.7	14.8	13.9	12.6	11.2	9.8	8.1	6.3	4.3
17.....	15.7	14.7	12.8	10.5	8.3	6.1	15.7	14.8	13.3	11.9	10.4	8.7	6.7	4.6
18.....	16.7	15.6	13.5	11.2	8.8	6.5	16.7	15.7	14.1	12.6	11.0	9.2	7.2	4.8
19.....							17.6	16.5	14.8	13.3	11.7	9.8	7.6	5.1
20.....							18.6	17.3	15.5	13.9	12.3	10.4	8.1	5.4
21.....							19.5	18.2	16.3	14.6	13.0	10.9	8.5	5.6
22.....							20.5	19.2	17.1	15.3	13.6	11.5	8.9	5.8
23.....							21.5	20.0	17.8	16.0	14.2	12.0	9.4	6.2
24.....							22.5	20.9	18.6	16.7	14.9	12.6	9.9	6.4

TABLE 14.—*Diameters inside bark at different heights above the ground for trees of different sizes, etc.*—Continued.

80-FOOT TREES.

Diameter breasthigh.	Height above ground—feet.								
	4.5	9.15	17.3	25.45	33.6	41.75	49.9	58.05	66.2
Inches.	Diameter inside bark—inches.								
8.....	7.4	7.1	6.6	6.1	5.5	4.9	4.1	3.2	2.2
9.....	8.3	7.9	7.3	6.8	6.2	5.5	4.6	3.6	2.5
10.....	9.2	8.7	8.1	7.6	7.0	6.1	5.1	4.0	3.0
11.....	10.1	9.6	8.9	8.3	7.6	6.7	5.6	4.5	3.3
12.....	11.0	10.4	9.7	9.0	8.3	7.2	6.1	4.9	3.6
13.....	11.9	11.3	10.5	9.8	8.9	8.0	6.7	5.4	4.0
14.....	12.9	12.2	11.3	10.5	9.6	8.6	7.3	5.8	4.3
15.....	13.8	13.0	12.1	11.3	10.3	9.2	7.8	6.3	4.7
16.....	14.8	14.0	13.0	12.0	11.0	9.8	8.4	6.8	5.0
17.....	15.7	14.9	13.8	12.7	11.7	10.5	8.9	7.2	5.4
18.....	16.7	15.8	14.6	13.5	12.3	11.1	9.5	7.7	5.8
19.....	17.6	16.7	15.4	14.3	13.0	11.7	10.0	8.2	6.2
20.....	18.6	17.5	16.3	15.0	13.7	12.3	10.6	8.7	6.5
21.....	19.5	18.5	17.0	15.7	14.4	12.9	11.2	9.2	6.8
22.....	20.5	19.4	17.9	16.5	15.1	13.6	11.8	9.7	7.2
23.....	21.5	20.4	18.7	17.3	15.9	14.3	12.4	10.2	7.6
24.....	22.5	21.2	19.5	18.0	16.5	14.9	13.0	10.7	7.8
25.....	23.5	22.2	20.3	18.8	17.2	15.6	13.6	11.3	8.2
26.....	24.5	23.1	21.2	19.5	17.9	16.3	14.2	11.7	8.5
27.....	25.5	24.1	22.0	20.3	18.7	17.0	14.8	12.3	8.9
28.....	26.5	25.2	23.0	21.2	19.5	17.7	15.5	12.9	9.4
29.....	27.5	26.0	23.6	21.8	20.2	18.4	16.0	13.3	9.7
30.....	28.5	26.9	24.5	22.6	20.9	19.0	16.6	13.9	10.1

90-FOOT TREES.

Diameter breasthigh.	Height above ground—feet.										
	4.5	9.15	17.3	25.45	33.6	41.75	49.9	58.05	66.2	74.35	82.5
Inches.	Diameter inside bark—inches.										
8.....	7.4	7.1	6.8	6.5	6.2	5.8	5.2	4.6	4.0	3.2	1.9
9.....	8.3	8.0	7.6	7.3	7.0	6.5	5.8	5.2	4.5	3.5	2.0
10.....	9.2	8.8	8.4	8.1	7.7	7.0	6.4	5.7	4.9	3.8	2.2
11.....	10.1	9.7	9.2	8.9	8.4	7.7	6.9	6.1	5.2	4.2	2.4
12.....	11.0	10.6	10.0	9.6	9.0	8.3	7.5	6.6	5.6	4.5	2.6
13.....	11.9	11.5	10.9	10.3	9.7	9.0	8.0	7.0	6.0	4.8	2.7
14.....	12.9	12.4	11.7	11.1	10.5	9.5	8.6	7.6	6.5	5.1	3.0
15.....	13.8	13.2	12.4	11.8	11.1	10.2	9.1	8.0	6.9	5.4	3.1
16.....	14.8	14.1	13.2	12.6	11.8	10.8	9.7	8.6	7.3	5.8	3.4
17.....	15.7	15.0	14.0	13.3	12.5	11.5	10.4	9.1	7.7	6.1	3.5
18.....	16.7	15.9	14.9	14.0	13.2	12.2	11.0	9.6	8.1	6.4	3.8
19.....	17.6	16.8	15.6	14.7	13.8	12.8	11.5	10.1	8.5	6.7	3.9
20.....	18.6	17.7	16.5	15.5	14.6	13.4	12.1	10.6	9.0	7.0	4.0
21.....	19.5	18.6	17.3	16.3	15.2	14.1	12.7	11.2	9.4	7.3	4.3
22.....	20.5	19.5	18.1	17.0	16.0	14.7	13.3	11.7	9.9	7.7	4.5
23.....	21.5	20.4	18.9	17.8	16.7	15.4	13.9	12.3	10.3	8.0	4.6
24.....	22.5	21.4	19.7	18.5	17.4	16.0	14.5	12.9	10.8	8.3	4.9
25.....	23.5	22.2	20.5	19.3	18.0	16.7	15.1	13.4	11.3	8.7	5.1
26.....	24.5	23.2	21.4	20.0	18.8	17.3	15.7	14.0	11.7	9.0	5.2
27.....	25.5	24.1	22.1	20.7	19.4	18.0	16.3	14.6	12.3	9.4	5.4
28.....	26.5	25.1	23.0	21.4	20.0	18.6	17.0	15.2	12.8	9.8	5.6
29.....	27.5	26.0	23.8	22.1	20.8	19.3	17.5	15.7	13.3	10.1	5.7
30.....	28.5	26.9	24.6	22.8	21.4	19.9	18.2	16.3	13.8	10.6	6.0
31.....	29.5	27.9	25.3	23.5	22.1	20.6	18.7	16.8	14.3	11.0	6.1
32.....	30.5	28.9	26.3	24.2	22.8	21.3	19.4	17.4	14.9	11.4	6.2
33.....	31.5	29.7	27.0	24.9	23.4	21.9	20.0	18.0	15.5	11.8	6.4
34.....	32.5	30.7	27.8	25.6	24.1	22.6	20.7	18.6	16.0	12.4	6.5
35.....	33.5	31.6	28.4	26.3	24.8	23.2	21.3	19.2	16.6	12.8	6.7
36.....	34.5	32.6	29.3	27.0	25.4	23.8	21.9	19.7	17.1	13.2	6.8

TABLE 14.—*Diameters inside bark at different heights above the ground for trees of different sizes, etc.—Continued.*

100-FOOT TREES.

Diameter breasthigh.	Height above ground—feet.											
	4.5	9.15	17.3	25.45	33.6	41.75	49.9	58.05	66.2	74.35	82.5	90.65
Inches.	Diameter inside bark—inches.											
12.....	11.0	10.5	10.1	9.8	9.3	8.7	8.0	7.4	6.7	5.8	4.3	2.4
13.....	11.9	11.4	10.9	10.5	10.0	9.4	8.6	8.0	7.2	6.2	4.7	2.6
14.....	12.9	12.3	11.7	11.3	10.7	10.0	9.3	8.5	7.7	6.6	5.0	2.8
15.....	13.8	13.2	12.6	12.0	11.4	10.7	9.9	9.1	8.1	7.0	5.4	2.9
16.....	14.8	14.0	13.4	12.8	12.1	11.4	10.5	9.6	8.6	7.4	5.7	3.1
17.....	15.7	14.9	14.2	13.6	12.7	12.0	11.2	10.2	9.1	7.8	6.0	3.2
18.....	16.7	15.8	15.0	14.3	13.5	12.7	11.8	10.8	9.6	8.2	6.3	3.5
19.....	17.6	16.7	15.9	15.1	14.1	13.3	12.4	11.3	10.1	8.7	6.7	3.7
20.....	18.6	17.7	16.6	15.7	14.9	14.0	13.0	11.9	10.6	9.1	7.0	3.9
21.....	19.5	18.6	17.6	16.6	15.6	14.6	13.6	12.5	11.1	9.5	7.4	4.1
22.....	20.5	19.5	18.3	17.3	16.2	15.3	14.3	13.1	11.6	10.0	7.7	4.3
23.....	21.5	20.4	19.1	18.0	16.9	16.0	14.9	13.6	12.1	10.4	8.1	4.5
24.....	22.5	21.3	20.0	18.7	17.6	16.7	15.5	14.2	12.6	10.9	8.4	4.7
25.....	23.5	22.3	20.8	19.5	18.3	17.3	16.0	14.7	13.2	11.3	8.7	4.8
26.....	24.5	23.3	21.6	20.2	19.0	17.9	16.6	15.3	13.7	11.7	9.0	5.0
27.....	25.5	24.2	22.4	20.9	19.7	18.5	17.2	15.8	14.2	12.2	9.3	5.2
28.....	26.5	25.2	23.2	21.6	20.4	19.1	17.8	16.4	14.7	12.6	9.6	5.4
29.....	27.5	26.1	24.0	22.3	21.0	19.8	18.4	16.9	15.2	13.1	10.0	5.6
30.....	28.5	27.1	24.8	23.0	21.7	20.5	19.0	17.5	15.7	13.5	10.3	5.8
31.....	29.5	28.0	25.5	23.7	22.3	21.1	19.6	18.1	16.3	13.9	10.6	6.0
32.....	30.5	28.9	26.3	24.4	23.0	21.7	20.2	18.6	16.8	14.4	10.9	6.3
33.....	31.5	29.7	27.0	25.0	23.6	22.3	20.8	19.1	17.3	14.8	11.3	6.5
34.....	32.5	30.7	27.8	25.7	24.3	23.0	21.4	19.7	17.9	15.3	11.6	6.7
35.....	33.5	31.5	28.5	26.4	25.0	23.6	22.0	20.3	18.4	15.8	11.9	6.9
36.....	34.5	32.5	29.4	27.2	25.7	24.2	22.6	20.8	19.0	16.3	12.3	7.1

110-FOOT TREES.

Diameter breasthigh.	Height above ground—feet.													
	4.5	9.15	17.3	25.45	33.6	41.75	49.9	58.05	66.2	74.35	82.5	90.65	98.8	106.95
Inches.	Diameter inside bark—inches.													
14.....	12.9	12.5	11.9	11.2	10.6	10.1	9.6	9.0	8.2	7.3	6.3	5.0	2.9	.....
15.....	13.8	13.4	12.7	12.0	11.3	10.7	10.1	9.5	8.8	7.8	6.7	5.3	3.1	.....
16.....	14.8	14.2	13.5	12.8	12.1	11.4	10.8	10.1	9.3	8.3	7.1	5.5	3.2	.....
17.....	15.7	15.1	14.3	13.5	12.8	12.1	11.4	10.7	9.8	8.8	7.5	5.8	3.4	.....
18.....	16.7	16.0	15.1	14.3	13.5	12.8	12.1	11.3	10.3	9.3	7.9	6.0	3.5	.....
19.....	17.6	16.9	16.0	15.1	14.3	13.5	12.6	11.9	10.9	9.7	8.3	6.3	3.7	.....
20.....	18.6	17.8	16.8	15.9	15.1	14.2	13.3	12.4	11.4	10.2	8.7	6.6	3.9	.....
21.....	19.5	18.7	17.6	16.7	15.8	14.9	13.9	13.0	11.9	10.7	9.1	6.8	4.0	.....
22.....	20.5	19.7	18.4	17.4	16.5	15.5	14.6	13.6	12.5	11.2	9.5	7.1	4.2	.....
23.....	21.5	20.6	19.3	18.2	17.1	16.2	15.2	14.2	13.0	11.7	9.9	7.3	4.3	.....
24.....	22.5	21.5	20.2	18.9	17.9	16.9	15.9	14.8	13.6	12.2	10.3	7.7	4.5	.....
25.....	23.5	22.5	21.0	19.7	18.6	17.6	16.6	15.4	14.1	12.7	10.7	8.0	4.6	.....
26.....	24.5	23.4	21.8	20.4	19.3	18.3	17.2	16.0	14.7	13.2	11.2	8.2	4.8	.....
27.....	25.5	24.3	22.6	21.1	20.0	18.9	17.8	16.6	15.2	13.7	11.5	8.6	4.9	.....
28.....	26.5	25.2	23.4	21.9	20.7	19.6	18.4	17.2	15.8	14.1	11.9	8.8	5.1	.....
29.....	27.5	26.2	24.2	22.6	21.4	20.3	19.0	17.7	16.3	14.7	12.3	9.1	5.2	.....
30.....	28.5	27.1	24.9	23.3	22.1	20.9	19.6	18.3	16.9	15.2	12.8	9.4	5.4	.....
31.....	29.5	28.1	25.8	24.0	22.7	21.5	20.2	18.9	17.4	15.7	13.2	9.7	5.5	.....
32.....	30.5	29.0	26.6	24.7	23.3	22.1	20.8	19.4	18.0	16.2	13.5	10.1	5.7	.....
33.....	31.5	29.9	27.3	25.4	24.0	22.7	21.4	20.0	18.5	16.6	14.0	10.3	5.8	.....
34.....	32.5	30.9	28.1	26.0	24.6	23.3	22.0	20.6	19.1	17.2	14.4	10.7	6.0	.....
35.....	33.5	31.8	28.9	26.7	25.3	24.1	22.6	21.1	19.6	17.6	14.8	10.9	6.1	.....
36.....	34.5	32.7	29.6	27.3	25.9	24.6	23.2	21.7	20.1	18.1	15.2	11.3	6.3	.....

TABLE 14.—*Diameters inside bark at different heights above the ground for trees of different sizes, etc.*—Continued.

Diameter breast-high.	120-FOOT TREES.														
	Height above ground—feet.														
	4.5	9.15	17.3	25.45	33.6	41.75	49.9	58.05	66.2	74.35	82.5	90.65	98.8	106.95	115.1
Inches.	Diameter inside bark—inches.														
16.....	14.8	14.3	13.6	12.8	12.1	11.5	10.7	10.1	9.4	8.7	7.9	6.8	5.0	3.1	.....
17.....	15.7	15.2	14.4	13.6	12.9	12.2	11.4	10.8	10.0	9.2	8.3	7.1	5.3	3.3	.....
18.....	16.7	16.1	15.2	14.4	13.6	12.9	12.2	11.4	10.5	9.7	8.8	7.5	5.6	3.5	.....
19.....	17.6	17.0	16.1	15.2	14.3	13.5	12.7	12.0	11.2	10.2	9.3	7.9	5.9	3.7	.....
20.....	18.6	17.9	16.9	15.9	15.0	14.3	13.4	12.6	11.8	10.8	9.6	8.2	6.2	3.8	.....
21.....	19.5	18.8	17.7	16.7	15.8	15.0	14.1	13.3	12.3	11.3	10.1	8.6	6.5	4.0	.....
22.....	20.5	19.7	18.6	17.4	16.5	15.7	14.8	13.9	12.9	11.8	10.6	9.0	6.8	4.2	.....
23.....	21.5	20.7	19.4	18.2	17.2	16.4	15.5	14.5	13.5	12.4	11.0	9.3	7.1	4.4	.....
24.....	22.5	21.6	20.2	19.0	18.0	17.1	16.2	15.1	14.0	12.9	11.5	9.7	7.4	4.5	.....
25.....	23.5	22.5	21.0	19.7	18.7	17.8	16.8	15.8	14.7	13.5	12.0	10.1	7.6	4.7	.....
26.....	24.5	23.5	21.9	20.5	19.4	18.5	17.5	16.4	15.3	13.9	12.4	10.4	7.9	4.9	.....
27.....	25.5	24.4	22.7	21.2	20.1	19.2	18.2	17.1	15.9	14.5	12.8	10.8	8.1	5.1	.....
28.....	26.5	25.3	23.5	22.0	20.8	19.8	18.8	17.6	16.4	15.0	13.3	11.1	8.4	5.2	.....
29.....	27.5	26.2	24.3	22.7	20.5	21.5	19.4	18.2	17.0	15.6	13.7	11.5	8.6	5.4	.....
30.....	28.5	27.2	25.1	23.4	22.2	21.2	20.1	18.8	17.5	16.1	14.2	11.8	8.9	5.6	.....
31.....	29.5	28.1	25.9	24.1	22.8	21.8	20.7	19.4	18.0	16.5	14.6	12.1	9.1	5.8	.....
32.....	30.5	29.1	26.7	24.8	23.5	22.5	21.3	20.0	18.6	17.1	15.1	12.5	9.4	5.9	.....
33.....	31.5	30.0	27.5	25.5	24.2	23.0	21.9	20.6	19.1	17.6	15.5	12.8	9.6	6.1	.....
34.....	32.5	30.9	28.3	26.2	24.8	23.7	22.5	21.1	19.7	18.1	16.0	13.2	9.9	6.2	.....
35.....	33.5	31.9	29.0	27.0	25.5	24.3	23.1	21.7	20.2	18.6	16.4	13.5	10.1	6.5	.....
36.....	34.5	32.8	29.9	27.7	26.2	24.9	23.7	22.3	20.7	19.1	16.9	13.9	10.4	6.6	.....

130-FOOT TREES.															
18.....	16.7	16.2	15.3	14.4	13.6	12.8	12.0	11.4	10.7	10.0	9.4	8.8	7.6	5.7	3.5
19.....	17.6	17.1	16.2	15.3	14.4	13.6	12.8	12.0	11.3	10.6	9.9	9.3	7.9	6.0	3.7
20.....	18.6	18.0	17.1	16.1	15.2	14.3	13.5	12.7	11.9	11.1	10.4	9.6	8.3	6.3	4.0
21.....	19.5	18.9	17.9	16.9	15.9	15.0	14.3	13.4	12.6	11.8	11.0	10.1	8.6	6.6	4.2
22.....	20.5	19.8	18.7	17.6	16.6	15.7	14.9	14.0	13.1	12.2	11.4	10.5	8.9	6.9	4.5
23.....	21.5	20.8	20.5	18.4	17.4	16.5	15.6	14.7	13.8	12.9	11.9	10.9	9.3	7.2	4.7
24.....	22.5	21.7	19.5	19.1	18.1	17.2	16.3	15.4	14.4	13.4	12.4	11.3	9.6	7.5	5.0
25.....	23.5	22.7	21.2	19.9	18.8	18.0	17.0	16.0	15.0	13.9	12.8	11.6	9.9	7.8	5.2
26.....	24.5	23.6	22.0	20.6	19.6	18.7	17.7	16.7	15.6	14.5	13.4	12.1	10.3	8.1	5.5
27.....	25.5	24.5	22.8	21.4	20.2	19.3	18.4	17.3	16.1	15.1	13.8	12.5	10.6	8.4	5.6
28.....	26.5	25.4	23.7	22.1	20.9	20.0	19.1	18.0	16.8	15.6	14.3	12.9	11.0	8.6	5.9
29.....	27.5	26.3	24.4	22.9	21.7	20.7	19.7	18.6	17.4	16.2	14.8	13.2	11.3	8.9	6.1
30.....	28.5	27.2	25.3	23.6	22.3	21.3	20.3	19.2	18.0	16.7	15.2	13.6	11.6	9.1	6.3
31.....	29.5	28.2	26.0	24.3	23.0	22.0	21.0	19.9	18.6	17.3	15.7	14.0	11.9	9.4	6.5
32.....	30.5	29.1	26.9	25.1	23.7	22.7	21.7	20.5	19.2	17.7	16.2	14.4	12.3	9.7	6.7
33.....	31.5	30.1	27.7	25.8	24.4	23.3	22.3	21.1	19.8	18.3	16.6	14.7	12.7	10.0	6.9
34.....	32.5	31.0	28.5	26.5	25.1	24.0	23.0	21.7	20.4	18.9	17.1	15.1	13.0	10.2	7.2
35.....	33.5	31.9	29.3	27.3	25.8	24.6	23.6	22.4	21.0	19.5	17.6	15.5	13.3	10.5	7.4
36.....	34.5	32.8	30.1	27.9	26.4	25.3	24.2	23.0	21.6	20.0	18.0	15.9	13.6	10.8	7.6

YIELD (SMALL SAMPLE AREAS).

The yield of the black willow varies greatly. Typically mature willow is usually found with cottonwood, occasionally in extensive pure stands. Even when grown with cottonwood it often occurs in pure groups or pockets of from 10 to 100 trees. Of the sample plots listed in the following table, Nos. 1, 2, and 3, near Helena, Ark., were selected from an area of several hundred acres on which willow occurred in varying amounts, averaging about 33 per cent of the total stand. In plots 4, 5, and 6, near Rodney, Miss., the willow was mixed with cottonwood and made up only about 8 per cent of the

total stand on approximately 1,000 acres. It occurred generally in groups one-eighth acre to 3 or 4 acres in extent. In plots 7, 8, and 9, on Raccourci Island, Williamsport, La., the willow stand was almost pure over several thousand acres. At other places the plots were in pure stands, ranging from 1 acre to 100 acres. In scaling the plots Table 9 was used. The top diameters shown in Table 5 more nearly represent the actual practice in cutting willow under the present wasteful lumbering, but in order to make a fairer comparison with cottonwood or other species more closely utilized it was considered desirable to base the yield on approximately the same utilization as for cottonwood.

TABLE 15.—*Yield of black willow in the Mississippi Valley south of Cairo, Ill.*

WELL-STOCKED STANDS.

Plot No.	Location.	Size of plot.	Age.	Trees per acre.	Average height.	Yield per acre		
	State.	Acres.	Years.		Feet.	Cubic feet.	Board ft.	Cords.
12.....	Missouri.....	0.25	35	76	84	6,608	28,320	66
11.....	Tennessee.....	.25	40	84	90	8,968	41,920	89
10.....	do.....	.50	45	98	90	10,418	46,820	104
5.....	Mississippi.....	.50	45	34	116	6,124	30,340	61
4.....	do.....	.25	47	56	116	7,888	41,280	79
6.....	do.....	.25	50	52	116	8,140	39,840	81
7.....	Louisiana.....	2.50	55	41	110	7,800	38,360	78
8.....	do.....	1.00	55	36	107	7,004	33,989	70
1.....	Arkansas.....	.25	55	64	110	1,008	49,760	90
2.....	do.....	.25	58	40	106	6,113	30,960	61
3.....	do.....	.25	58	56	109	9,016	48,560	90
9.....	Louisiana.....	2.50	58	56	103	6,809	42,280	87

UNDERSTOCKED STANDS.

21.....	Mississippi.....	0.25	27	52	104	5,488	25,360	55
13.....	Missouri.....	.25	37	58	75	4,992	20,800	50
14.....	do.....	.25	41	62	62	4,836	19,400	48
19.....	Mississippi.....	.25	47	32	105	4,300	20,720	43
20.....	do.....	.25	47	32	100	4,640	22,400	46
16.....	Arkansas.....	.25	49	36	97	4,556	21,440	46
15.....	do.....	.25	50	36	96	5,356	25,800	54
17.....	Tennessee.....	.25	51	56	86	5,482	24,400	55
18.....	do.....	.25	51	68	66	6,208	27,280	62
22.....	Louisiana.....	.25	55	28	94	3,844	26,404	38

MANAGEMENT OF WILLOW ON OVERFLOW BOTTOM LANDS.

The black willow is now receiving the attention of lumbermen because it is a substitute for cottonwood, which is being rapidly exhausted, and because it is especially adapted for management on the Mississippi bottom lands. The failing supply of cottonwood will be largely replaced by red gum for some purposes; but black willow must also become increasingly prominent, for it can be used in many ways and it is much lighter in weight than red gum, which, on account of the long distances this lumber must be shipped to reach the northern markets, is a decided advantage.

Cottonwood is a better tree for planting than willow, but for the management of natural growth black willow is in many respects superior. It seeds as abundantly as cottonwood, reproduces by cuttings, and survives, when young, a greater variety of unfavorable conditions. The land that is in no danger of being inundated, covered

with sediment, or cut away by the river, is too valuable agriculturally to be used for forest plantations. This leaves only overflow lands for forest purposes, and the condition of these is so unstable as to make the artificial establishment of plantations too precarious an investment to attract capital. The inferior timber on the ground and the natural reproduction will therefore continue to be utilized instead of better species being planted. Under these conditions the probability of success in forest management is greater with willow than with cottonwood.

The main problem in the management of bottom lands is how to encourage the best species. In this discussion the lands considered are those lying below the 35-foot stage of the river. Above this mark the willows are usually replaced by better species. The lower areas are covered by a mixture of black willow, cottonwood, and sandbar willow, the last being both the most prolific and the least desirable. In the management of such areas the only way at present of encouraging the best species is to cut intelligently the material used in revetment work. By limiting the cuttings to stands of sandbar willow and leaving the cottonwood and black willow, the prevalence of the sandbar willow can be much reduced. In mixed stands, 7 to 12 years old, where all three species occur, all the cottonwood and enough of the black willow to stock the ground completely should be left. If from 200 to 300 trees of cottonwood or black willow be left to the acre, the first crop of willows for revetment will suffer but a slight reduction and the second crop of sprout growth will receive but little shading from the trees left. The third crop of revetment willows will necessarily be smaller, but such a thinning can easily be made profitable; then after the period of these two crops, ranging from 10 to 15 years, the original trees left will soon make a complete canopy. By this method, at practically no expense more than directing the cutting of the brush, a worthless area covered with mixed growth may be converted into timberland of considerable value. In further thinnings the cottonwood, if present, should be favored except on land that is receiving large accretions. On such land the black willow generally survives the cottonwood.

CHARACTERISTICS OF WILLOW WOOD.

Willow is characteristically a light wood. It varies considerably in weight in different species and under different growing conditions. The wood of the slow-growing species and shrubby forms is usually heavier than that of the larger and more rapid-growing species. The diamond willow is heavier and harder than the other native willows of economic importance. There is little difference in the weight of the wood of black, white, and crack willows, the specific gravity ranging from 0.4 to 0.45.

The wood of the male trees of the white willow is heavier than that of the female trees of the same species ¹ and on the same soil. This may be due to the usually faster growth of the pistillate trees that has been frequently observed. In planting to obtain wood for a particular purpose this characteristic should be taken into consideration.

Willow wood in the sap is whitish to creamy yellow and in the heart pink to reddish brown. Occasionally the heart of the black willow of the lower Mississippi is a light bluish gray when dry.

The annual rings of all willows are relatively indistinct, the wood being quite uniform throughout. The rings of white and crack willow are much less distinct than those of the black willow. The black willow can be readily distinguished from the other two species even without a hand lens, provided a smooth transverse surface is cut. No clear and constant distinction was found between the white and crack willows. The white willow shows a tendency toward being more porous in the early wood, the pores often being larger than those in the crack willow, so that the medullary rays bend around them, but their character is not constant and occasionally the crack willow shows the same structure.

TO DISTINGUISH WHITE AND BLACK WILLOW WOOD.

In the black willow wood (*Salix nigra*) the pores diminish considerably in size and number toward the outer portion of the growth ring, with a strong tendency toward being grouped in wavy tangential lines in the late wood. The heartwood is of a dirty reddish-brown or grayish-brown color. In the white willow wood (*Salix alba vitellina* and *Salix fragilis*) the pores diminish only slightly in size and number toward the outer portion of the growth ring and do not have the tendency toward being grouped in wavy tangential lines in the late wood. The heartwood is of a clear salmon-brown color.

USES OF WILLOW WOOD.

LUMBER.

According to census reports and millmen in the South, willow lumber has been cut in limited quantities for the last 8 or 10 years. It was marketed and used locally under the name of black or brown cottonwood until the last 7 years. Since then the production has increased until willow has found a place on the market under its true name. Practically all of the material so utilized has been cut from the black willow on the lower Mississippi, principally between Memphis, Tenn., and Baton Rouge, La., although small quantities

¹ E. R. Platt, "The variations of *Salix alba*," Quar. Jour. Forestry.

have been manufactured in the Middle Western States from planted groves of white and crack willow. The white and crack willow lumber is used locally in farm buildings and to a small extent in rough interior carpentry work. Much of the black willow is barged up the Mississippi to the vicinity of Cairo, Ill., where it is graded and distributed through the Northern States, principally in Iowa, Illinois, Michigan, and Wisconsin.

The average grade of willow lumber on the market is high, because only large clear logs are at present sawed into lumber. This entails great waste in the woods, as only a small part of the tree is taken. With a closer utilization the percentage of the poorer grades will increase considerably. The average willow now being cut is very little inferior to the average cottonwood. The following table shows the grades from average and select logs of willow, as compared with cottonwood, along the lower Mississippi:

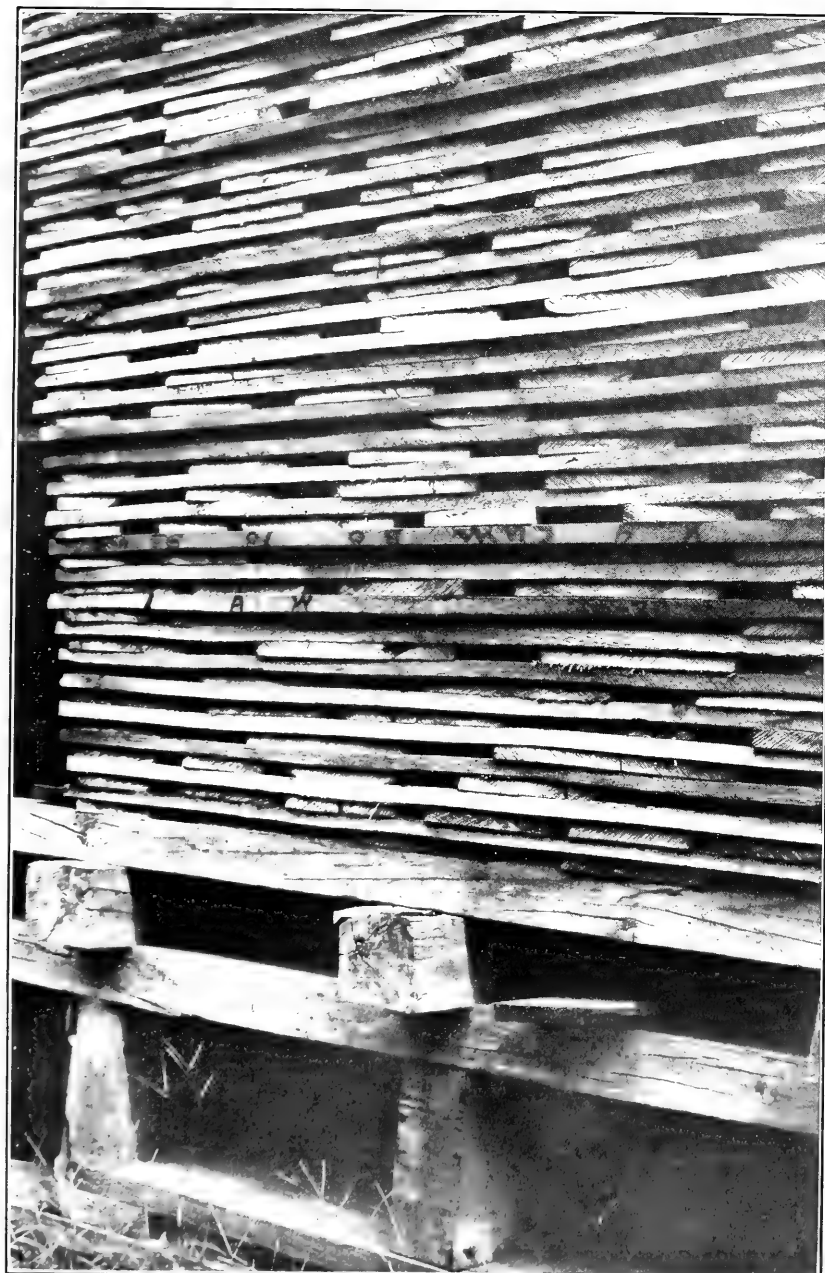
	Cottonwood. ¹		Black willow. ²		Black willow, mill run, lumber graded at Cairo, Ill.
	Select logs.	Average.	Select logs.	Average.	
	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>
Boxboards.....	7	9	5		
Firsts and seconds.....	40	18	30	20	32
No. 1 common.....	35	30	25	30	40
No. 2 common.....	15	42	38	48	25
No. 3 common.....	5	1			3
Mill cull.....			2	2	

¹ Department of Agriculture Bulletin 24.

² Based on annual mill-cut figures at two 20,000 daily capacity mills.

The price of willow lumber has increased steadily since it was put on the market. It was first shipped North in 1909 or 1910 and sold at from \$10 to \$12 per thousand, mill run, f. o. b. at the mill. At this price there was no profit for the manufacturer, and the lumber was secured and cut more or less as an experiment. It was easily marketed, and a request was immediately made for more. Since that time the price has risen to \$16 per thousand, mill run. In Chicago and Grand Rapids furniture manufacturers pay from \$24 to \$25 per thousand for clear lumber. Further rises will only follow the general market. At present the cost of handling willow lumber is as high as is usually the case with a new product. Most of the willow shipped North is handled several times, and this adds materially to the cost. With a low-grade lumber it is especially important that it be handled as directly as possible.

A number of sawmills and cooperage mills on the lower Mississippi, visited in the fall of 1913 in the course of this study, reported that they were using between 23,000,000 and 25,000,000 feet of black willow. Half of this went into box shooks or slack cooperage stock. Sawmills, in reporting their annual production of lumber,



F-1526A

PILED WILLOW LUMBER, NO. 1 COMMON, VICKSBURG, MISS., 1913.



P-15888A

CUTTING BOLTS FOR EXCELSIOR FROM YOUNG STANDS OF BLACK WILLOW ALONG THE WABASH RIVER IN SOUTHERN INDIANA, 1913.

often list willow as cottonwood, so that available statistics do not indicate the full production of willow lumber.

Willow lumber is light, 1-inch lumber weighing when thoroughly seasoned from 2,300 to 2,500 pounds per thousand board feet. This makes it as cheap to transport as yellow poplar. The wood varies in color considerably. When first cut it runs from dark reddish brown to blue and almost black, but when dry it is much lighter. Thoroughly seasoned wood is for the most part a light reddish brown with perhaps 10 per cent of it a grayish blue. Willow lumber, cut from only the best trees, as is the custom now, is seldom shaky, and when properly handled it checks scarcely at all. With close utilization the percentage of shaky lumber would increase considerably. Willow planking is satisfactory where strength is not of prime importance, since it does not warp, splinter, or check, and wears out very slowly. It makes good barn and cell floors. The grades of willow lumber are firsts and seconds, No. 1 and No. 2 common, and the grading rules are similar to those used for cottonwood.

Willow lumber of the high grades is used mostly in the North for furniture drawers and backing, while the poorer grades are used largely in the South for box material. As a substitute wood willow is very promising and for many uses equal to basswood. In fact, for many of the purposes for which willow was once used and for which it has scarcely a superior, basswood, poplar, and cottonwood were substituted because of their prevalence and relatively low cost. As willow comes back on the market at a lower price than these it bids fair to gain favor.

A part of the willow lumber now manufactured is being used for refrigerators, pianos, cabinetwork, and furniture. Here it has taken the place of basswood, elm, or sap gum. As yet it has only been used for interior work, but it should eventually find a place in the manufacture of cheap furniture; for although it does not take a high polish, it takes a very attractive dull finish and can be stained to present a very creditable imitation of some of the costlier cabinet woods.

Willow is suitable for small boats and athletic goods because it may be dented and bruised without splintering, and for keels, water wheels, paddles, and bungs because it is durable in water. It has always been used by leather workers for lapboards, cutting boards, and cutting tables, for which its lightness and spongy softness make it particularly desirable. Intense heat will not warp or split willow; therefore it is suitable for sleeve or ironing boards and for wheelbarrows for carrying ore, coal, or ashes in hot furnace rooms. Toys and novelties are now being made of it. For these, low-grade lumber can be worked up very closely and the dark color is scarcely a drawback because most of such articles are stained or painted.

SLACK COOPERAGE STOCK.

For a number of years willow has been manufactured into slack cooperage stock in New Orleans and other places on the lower Mississippi River. It was reported in the census returns of 1907 as furnishing 2,000,000 staves and 106,000 sets of headings. In 1908 these figures had more than doubled, being 4,485,000 and 240,000, respectively. In 1909 the production dropped over 25 per cent, but in 1910 it increased again, and manufacturers state that since then the reduction in the supply of other woods has led to even greater use of willow. Louisiana has from the beginning led in the utilization of willow in slack cooperage. Most of the mills are located in the vicinity of New Orleans and receive their logs from as far up the river as Vicksburg. The stave mills take logs above 16 feet in length and 8 inches in diameter. These logs are secured at a low cost and rafted down the river. From near-by points off the river the mills also bring in considerable material by rail, which is generally bolted in the woods into 21-inch pieces for heading and 32-inch pieces for staves. Willow cooperage is produced in two grades, No. 1 being used principally for sugar, rice, and asphalt, and No. 2 for potatoes, oysters, bottles, garden truck, and vegetables. The cull stock goes into half barrels.

EXCELSIOR.

Excelsior mills have been using willow for several years, those in Kentucky, Indiana, Missouri, Kansas, and Tennessee especially. The principal species used so far has been the black willow. It is taken in small sizes, most of the trees being under 12 inches in diameter and under 20 years in age. Trees of this size when grown close together furnish bolts relatively straight and free from defects. The wood is also largely sap and is thus much lighter in color than could be got from older and larger trees. The bolts are generally cut $4\frac{1}{2}$ feet long in the woods and are then recut to 18 inches at the mill. The unit used in measuring this wood is a rank 4 by $4\frac{1}{2}$ by 8 feet. Most of the willow for this purpose has been cut during the growing season, because at that time the peeling can be done at low cost. In Indiana the chopper cuts the bark at the base of the standing tree and then strips it upward in three or four strips as far as possible. After the trees are felled, the stripping is completed before the bolting is done. The cost of felling by this method was not over 25 cents per cord. The long hanging strips of bark are also extremely useful in dropping the trees, as in thick mixed stands the trees are apt to lodge. Willow cut in winter requires almost as much time for peeling as for felling and bolting, and, at the present price of \$2 per rank for stacked, peeled, and split wood, a laborer would find it difficult to make fair wages.

Excelsior is usually manufactured into three grades—coarse, medium, and fine, the latter being called wood wool. Willow goes into the first two grades, but not into the wood wool, largely on account of its color. Pure willow excelsior is seldom seen, because the willow is usually worked in more or less as an adulterant. Candy manufacturers discriminate against willow excelsior on the ground that it taints their wares.

Excelsior manufacturers in Indiana pay \$7 to \$7.50 per rank delivered at the mill for peeled willow cut in $4\frac{1}{2}$ -foot lengths. The pieces must be not more than 6 inches in diameter or split so that at least one side of a quartered log is not wider than 6 inches.

CHARCOAL.

Though most of the charcoal manufactured is a side product of wood-distillation plants, the making of willow charcoal has been a separate industry for years. Willow charcoal is especially suitable for certain grades of black powder, and is in demand for chemical and medicinal purposes because it produces a very pure carbon. Several powder mills in the Eastern States, after having used all the native willows within many miles of the mill, have induced farmers to plant willows. These people, following the example of the powder mills, have grown "pollard" willows by setting out long poles and then cropping at intervals the sprouts produced at the top.

The general price paid for "powder willows" delivered at the mills has been \$6 per cord, green, or \$7.50 per cord, peeled. Peeling done in the winter has cost \$1.50 per cord. The sticks are 4 feet long and range in size from 1 inch to 5 inches. Above this size sticks are split. Splitting costs about \$1 per cord. Of late years willows have become so scarce in several of these localities that considerable material has been imported from a distance, and often the companies have paid the transportation charges, giving the mill prices for cordwood delivered at the nearest railroad point. No distinction is made between the different species of willows, as any willows of the desirable size seem to produce a high grade of charcoal.

PULP.

Willow wood is used to a limited extent for paper pulp, although its short fiber makes it useful only as a filler for the longer fibered woods. In the North, where most of the paper mills are located, willow does not occur in sufficient quantities to be given any particular attention. In the South, however, along the lower Mississippi and its tributaries, there is a good deal of willow which is not large enough for saw timber but would be suitable for pulpwood. On many thousands of acres trees from 5 to 15 inches in diameter form dense stands. These could for the most part be logged and transported

to a mill with great economy. The willow could be mixed with long-leaf pine, which has very long fibers and which is coming into use in the South for pulp.

Should willow become important in that region for pulp, black willow on the Mississippi bottoms offers ideal conditions for practicing forest management. The tree grows rapidly in dense natural stands and reproduces abundantly by seed or sprouts. The bottom lands are low priced and highly fertile, the growing season is long, transportation is cheap, and logging conditions excellent.

ARTIFICIAL LIMBS.

It is estimated that there are now in this country nearly 200 manufacturers of artificial limbs. The first artificial leg, other than the ordinary wooden pegs, is said to have been made in London by a man named Cork in the early part of the nineteenth century. Although very imperfect, this device was a great improvement over the old peg. The early name of "cork legs" was continued, and in time the public began to think that these legs were made of cork. The materials most commonly used are wood, leather, aluminum, fiber, or papier-mâché for the major parts and rubber and felt for the minor parts. The majority of manufacturers use some wood, usually willow. Of the species used the following are most common: White, yellow, crack, black, and peachleaf willows. In New York the yellow willow is the most commonly used, although both the white and crack willow are used occasionally. In the Lake States the white and crack willows are used the most, and are about equal in importance. The consumption of willow wood for this purpose offers to the enterprising farmer situated near a city a means of selling a portion of good willow trees at a fair price.

TRADE NAMES FOR SPECIES USED BY MANUFACTURERS.

The name "white willow" is usually applied to the sapwood of any willow and does not in the trade necessarily indicate the regular white willow, although it may. In Minnesota the crack willow is called white willow, as is also *Salix amygdaloides*, a common wild willow of that region, which is, however, seldom used. The wood called "white willow" in Minnesota is tough, full of knots, and hard to work. The wild willow, when it is used, generally goes into some part that does not come in contact with the body. It is considered heavier, more porous, and stronger than the wood called "red willow." The white willow of Missouri is *Salix amygdaloides* and is also known to the trade as swamp willow. The so-called imported English willow is all grown in the United States, but is doubtless from the species *Salix alba*, which is the English white willow. The Pennsylvania red willow of the trade is also *Salix alba*, and in this region the wood seems to be more reddish than farther west.

The wood of finest appearance is from the southern black willow, which comes in the market in two forms, the black and red heartwood. In the south the willow grows to be a forest tree, often with a clear length of over 50 feet, from the heartwood of which it is possible to cut a good many bolts large enough, even when quartered, for any requirement. The wood is clearer than the other species, and although several manufacturers declare it to be less tough and durable, it is very little, if any, inferior, provided it is cut at the proper time and thoroughly seasoned.

CUTTING AND SEASONING THE WOOD.

The consensus of opinion among manufacturers seems to be that the wood for artificial limbs should be cut in the winter. All, however, do not agree on this point. One claims that willow blocks cut in July and properly handled are as good as any he ever used. Most manufacturers consider it necessary for the wood to season for from one to three years, although an occasional exception to this rule is found. The trees used are generally large enough to allow the log sections to be quartered and still be 6 inches or over through the section. This would take a tree 12 inches or over in diameter. In a few cases the wood from smaller trees is used. Round blocks are not desirable, however, being apt to check because when they are worked the hollow portion generally corresponds too nearly to the annual rings. Only a very small portion of a tree cut for this purpose is utilized. Since the blocks must be quartered from straight logs free from knots, the average willow tree, especially when grown in the open, furnishes less than 10 feet of merchantable material. Trees that yield but one 4-foot section are often cut. The bark is generally removed at the time of cutting and splitting, but it may be left on the sticks until they are ready to be worked up. It is desirable to split the logs as soon as they are cut, as, otherwise, they may so check in drying as to spoil a portion of the wood. Many manufacturers also paint the ends of the sticks to prevent rapid drying and consequent splitting. It is also a common practice to bore a hole in the end for the same purpose. The wood is then stacked in a dry shed or left where there is a free circulation of air. The blocks are piled on dry wooden slats, so that they do not touch each other. Even after the blocks are treated in this manner there is often a loss of 10 to 30 per cent of the sticks, due to defects and rot.

The length of the blocks varies from 8 to 20 inches. The sticks are, however, brought in in 4, 6, or even 8 foot lengths and recut later. Many manufacturers cut their blocks in 16, 18, and 20 inch lengths. In diameter they range from 5 to 12 inches. Blocks 6 inches in diameter and 20 inches long weigh 9 or 10 pounds when dry. A block 5 inches in diameter and 16 inches long weighs about 7

pounds. It is claimed by some that sawed blocks are better than split blocks. Sawing the blocks would cost about 50 cents per 100 pieces.

The price paid for willow for this purpose varies greatly. Some manufacturers are able to buy fairly good material for almost cordwood prices. Others insist on higher class material and often pay several times as much for it, especially if it is brought from a distance. In Ohio 25 cents per block is paid for clear material averaging in size 5 by 5 by 16 inches. In Missouri fair material brings 50 cents a piece for pieces 6 by 6 inches by 4 feet and up. Fairly good wood may also be bought for \$8 to \$12 per cord. In Minnesota select wood brings \$30 to \$75 per thousand feet, board measure, or \$15 to \$30 per cord. In New York the price ranges from 15 cents to \$1.50 per stick, according to the size and quality.

BASKETS.

One of the most important commercial uses of willows at present is for willow furniture and baskets. For this purpose over 3,000,000 pounds of peeled willow rods are used every year, approximately half of this amount being grown in this country. Willows so grown are more of a farm than a forest crop. As a forest crop, they would be termed a system of coppice on a one-year rotation. Occasionally they are grown both for basket making and to protect the land they occupy from the ravages of floods. The crop may thus be made to pay for the labor involved in the planting and the protection afforded is often of great value. The principal species used in basket-willow culture are American Green, Purple, Lemley, and Patent Lemley, and to a smaller extent the Caspian willow. All of these are European species. Other European species such as the White Osier (*Salix viminalis*), which grow splendidly there, have not been successful in the United States. None of the native American species of willow are at present cultivated for basket-making purposes. Several species growing wild have, however, been used to a considerable extent locally. Chief among these species are the sandbar willow (*Salix fluviatilis*) and shiny willow (*Salix lucida*). The Forest Service is at present making a trial of the native species for basket-making purposes. Though it is too early to predict the outcome of these experiments, it can be said that a number of these species give evidence of being satisfactory basket willows. Further information in regard to basket-willow culture is contained in Farmers' Bulletin 622, "Basket Willow Culture."

POSTS.

There are many species that make better posts than willow, but in treeless regions and even in the better timbered localities its value should not be overlooked. Well-seasoned posts of the black or white

willow set in dry soil often last five to seven years. In soils that are alternately dry and wet and which freeze and thaw a great deal, willow posts are shorter lived, but under such conditions the life of any kind of post is much shortened. Posts of the diamond willow (*Salix cordata*) are very durable. More willow than cottonwood posts can usually be produced on a given area in a given time, especially if the trees are planted in rows, and willow posts are generally set in preference to cottonwood.

Willow wood is light, fairly porous, and quite easily treated. A treated willow post is practically as good as a treated post of any other species and much more durable than an untreated post of most species. Where good cedar, catalpa, locust, or Osage orange posts are obtainable for 20 to 30 cents, it would scarcely pay to use treated posts, but in many parts of the Middle West the average price of a red cedar post is approximately 40 cents. At this price it would be economical to use treated willow posts. First-class willow posts can be grown on good farm land for 12 cents apiece and second-class posts for 8 cents. These can be treated at a cost of 10 cents. Including the cost of peeling at 3 cents each, the cost of first-class creosoted posts is 25 cents and second-class posts 21 cents. Willow posts should be seasoned 8 or 10 weeks before being treated. Round posts are better for this purpose, as the penetration is better in sapwood than in heartwood. A willow post properly treated should last from 12 to 20 years. There seems to be a decided difference in opinion as to the value of seasoning untreated willow posts. At one experiment station it was found that usually seasoning was of little importance, but experience elsewhere does not altogether corroborate this observation. At Iowa Falls, Iowa, willow posts cut in the winter, seasoned with the bark on, then peeled and set out the following autumn, have had an average life of 10 years. At the same place willow posts cut in June and set out immediately lasted only 2 or 3 years. At numerous places in the prairie region seasoned willow posts have lasted 10 years, while most reports of decay in a short time also show that the posts were not seasoned. In setting willow posts care should be taken to avoid using material with doty heartwood. It may easily escape notice because the heart of willow shows very little discoloration until decay is far advanced.

TANNIN.

Willow bark is an important source of tannin in Europe, especially in Russia, France, Denmark, and Germany. In Russia it is used in the preparation of the finest leather, and combined with birch tar oil it produces the well-known scent of Russia leather. Von Höhnelt states that the crack willow (*Salix fragilis*) and basket willow (*Salix viminalis*) are the best for this purpose, containing 12 to 14 per cent

of tannin, while other species contain 6 to 11 per cent of tannin. H. G. Bennett in "The Manufacture of Leather" asserts that crack willow and *S. arenaria* contain 7 to 11 per cent of tannin and are commonly used. Alexander Watt in "Leather Manufacture" states that the bark of white willow (*S. alba*) and *S. cinerea* is used for tannin in France.

Tests made by the leather and paper laboratory of the Bureau of Chemistry of willow bark collected in 1914 at Arlington, Va., by the Forest Service, produced amounts of tannin as follows:

TABLE 16.—*Tannin in willow bark.*

Species.	Per cent total dissolved solids.	Per cent soluble solids.	Per cent nontannins.	Per cent tannins.	Number of samples.
<i>S. nigra</i> (trunk).....	16.16	15.10	8.38	6.71	11
<i>S. alba</i> (trunk).....	18.13	17.03	9.40	7.63	11
<i>S. fragilis</i> (trunk).....	23.32	22.27	14.12	8.49	12
<i>S. fragilis</i> (branches).....	19.62	18.04	9.64	8.40	9

Hemlock, chestnut oak, Spanish oak, black oak, hickory, and chestnut wood range above willow in tannin content, but in some cases the high tannin content is offset by the difficulty of securing or handling the bark.

The bark left in the woods in the making of excelsior and the peelings from basket willows, of which a large amount is often collected in one place, could be utilized at a low cost. If manufacturers of tannin extract could be interested in willow bark and assured of a sufficient supply, a profitable industry might be established.

OTHER USES.

Willows, because they produce flowers from which a high grade of honey can be obtained, have long been recognized as a useful bee plant, especially in early spring. Many beekeepers have set out willows especially for this purpose. Great care should be exercised in such planting to make sure that the cuttings are from staminate trees, as the pistillate flowers are of little value as a bee food.

In New Jersey, Delaware, and eastern Maryland willow is used for berry props and poles in truck gardening. For this purpose it is only fairly durable, but it is cheap and easy to secure.

The freedom of willow wood from checking and the ease with which it is worked make willow desirable as a carving wood and for picture frames, wooden shoes, and woodenware, such as bowls, scoops, ladles, and trays.



F-80658

FIG. 1.—POLLARDING WILLOWS FOR CHARCOAL WOOD USED IN MANUFACTURING OF GUNPOWDER.

Young healthy trees, beginning 2 years' growth after cropping. Wilmington, Del.

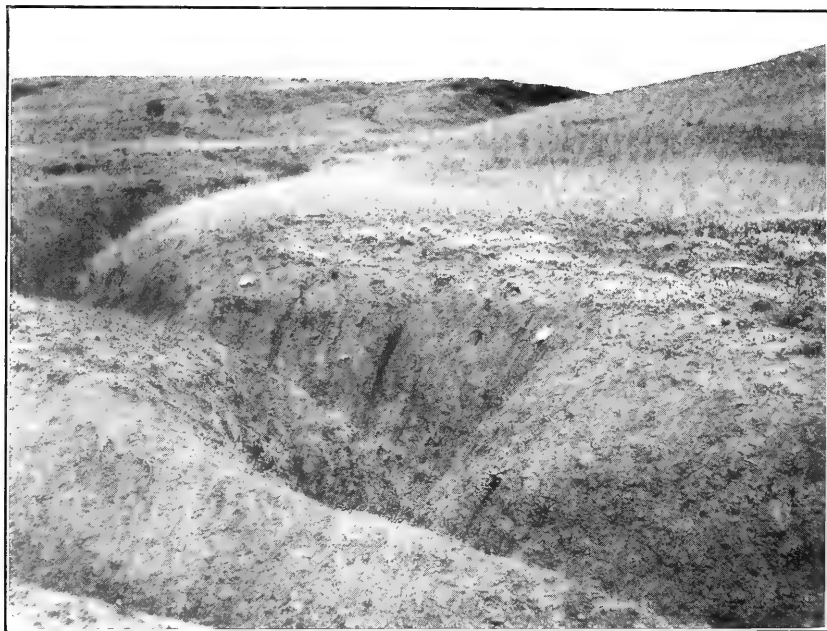


F-80659

FIG. 2.—POLLARD WILLOWS CROPPED THREE TIMES.

Trunk destroyed by injury due to floods and decay. Low stumps are more desirable in such situations. Wilmington, Del.

POLLARD WILLOWS.



F-12343A

FIG. 1.—A FIELD BADLY GULLIED AS A RESULT OF TOO HEAVY GRAZING.



F-369A

FIG. 2.—THE VIOLENT EFFECT OF A FRESHET ON LOOSE ALLUVIUM BANKS ON WHICH THE TREE GROWTH HAD RECENTLY BEEN REMOVED.

TWO PLACES WHERE WILLOWS COULD BE USED SUCCESSFULLY FOR PROTECTION.

USES OF WILLOWS FOR PROTECTION.

PROTECTION FROM EROSION.

The adaptability of willows to moist conditions and their rapid growth make them the best available plant for protecting soil from erosion by running water or wave action.

In Europe, especially in Russia, very definite methods have been worked out for protecting soil from gullying and for the building up and improvement of gullied fields. In this work willows have been largely used and have given the best results obtained from any of the numerous species tried. In this country farmers are just beginning to realize the importance of such protection and improvement work. Thousands of acres of abandoned fields would still be productive if proper preventive measures had been taken to check erosion. To the farmer who sees great holes gouged into his fields and the fertile top soil washed away from the land the question of devising some means of checking this devastation is of vital importance.

Most owners fail to appreciate the danger and allow the erosion to continue until the damage is done. Usually erosive action in a field is apparent first as sheet washing which is generally the forerunner of a gully. This can be stopped by the use of cover crops, judicious tillage, or in extreme cases by terraces and ditches. A gully already formed should be filled with brush, straw, or stone, or planted with some tree or shrub. It is surprising how fast a gully builds up when the bottom has been thickly planted with willows. They break the force of the current and catch and hold the sediment. This process would kill most trees, but the willows are able to survive and to eliminate a gully in a few seasons. The tree growth may then be removed so that farm implements can pass over, unless danger of a recurrence of the gully makes it necessary to keep the area in sod.

For the protection of stream banks willow plantations are generally the most effective, although cottonwood may also give good results. The best species to use are the vigorous growing wild ones found in the vicinity. Where native willows are not readily available, the white, yellow, crack, or weeping willow should give good results. Cuttings of any of these can be obtained cheaply from the various nursery dealers. The use of trees in the protection of stream banks is necessarily confined to creeks and small rivers and only to those having a medium velocity. Tree planting is generally without avail on caving banks of very swift streams, especially if the soil is loose, as it is also without avail along the large rivers even if they are not swift. These are problems for an engineer, although at the beginning the caving of a bank can often be prevented by proper treatment of the tree cover at dangerous places. Planting can be done success-

fully, however, along the smaller streams that in the aggregate destroy large areas of the richest land.

There are often places where floods have left perpendicular banks of soft soil, which, being constantly undermined by the current, cave in from time to time. It is very important that such places be protected, for such a bank is a constant menace to all the land lying back of it in the valley. Mechanical means of protection are generally expensive and are often not permanently effective. A good method of protecting soft alluvial banks is to make them sloping instead of perpendicular. This may require considerable grading, but it is absolutely necessary. After the bank has been reduced to a slope, the less precipitous the better, the face of it should be thickly planted with willow cuttings. For this purpose any willow material available in the vicinity is suitable. Cuttings from 1-year-old shoots up to stakes several inches in diameter will grow vigorously. In the more exposed places, especially near the water's edge, the larger sets are more satisfactory as they are less liable to be washed out before they have become firmly rooted. Willow is often more serviceable than walls of masonry, and the facility with which it is reproduced by seed, suckers, sprouts, and cuttings, both naturally and artificially, makes it both inexpensive and effective.

In places where conditions are more severe the following procedure has been successful:

Green willow poles 18 to 20 feet long are cut in the spring before growth begins; the poles are laid on the ground near the bank 2 or 3 feet apart with their butts toward the stream; woven wire fencing is then securely fastened to the poles, leaving 2 or 3 feet of the poles projecting below the wire if the margin of the stream is of soft mud and less than that if the bank is firmer. Sections of wire about 100 feet long can be handled to the best advantage. After the wire has been fastened to the poles, they are all pushed over the bank together so that the butts of the poles fall and sink into the soft mud at the water's edge. As the banks cave off some of the soil lodges on the wire, partially burying and weighting down the poles, which take root and grow. The wire serves to hold the mass of willows together until they have been firmly rooted. The ends of the wire are made secure by small wire cables running back up the bank and each one held by a "deadman." The caving and erosion of the bank soon round off its top edges and the growing willows catch and hold the soil, giving the bank the proper slope to resist erosion. Planting a few cuttings farther up the bank to hold this slope is often advantageous. This method can be varied by driving shorter posts firmly into the soil at the water's edge, but leaning somewhat toward the bank, and then attaching the woven wire. This holds the soil as it caves off, and as a slope is established it is planted with cuttings.

Another method which has been used to good advantage at the bends of small streams is to drive willow stakes 2 to 4 inches in diameter into the bank upward from the water's edge at low water and quite close together and to fill the spaces between them with loppings from willow trees or brush of all sizes, of which as much as possible is made to touch the ground or is partially buried. Additional forked stakes are useful in making the brush secure. This procedure insures a growth of willows that will protect the bank from further erosion.

In all operations for bank protection it is important to remember: (1) That a perpendicular caving bank must be made sloping before planting can be effective; (2) that planting should begin at the water line and proceed away from the stream; (3) that mechanical aids are often necessary to create conditions where planting can be done effectively; (4) that any part of a live willow and (usually) a cottonwood will grow vigorously if placed in moist soil.

BANK REVETMENT.

Willow is largely used in the making of mattresses for bank revetments along the lower Mississippi River and its tributaries. In one district alone, in 1913, 145,847 cords were used. The total amount of willow used for this purpose is from 300,000 to 400,000 cords per year. The trees are largely sandbar, peachleaf, or black willow, and are small, ranging from 1 to 5 inches in diameter and from 25 to 40 feet in length. In the New Orleans district cull lumber is used for the mats. This is partly because willows are not quite so plentiful in the lower portion of the valley and partly because the different districts working separately developed somewhat different methods of dealing with bank protection. Of the three species most commonly used the sandbar willow is the best. It is of slower growth than the other species, but it comes up in very dense stands and grows very straight. In thick stands it is practically free from branches except for a small crown. The habit this species has of sprouting prolifically from the roots insures a heavy stand when once started. The wood is slightly heavier than the other willows and somewhat tougher and stronger. Practically speaking, there is little difference in species, and contractors pay less attention to species than to size and form.

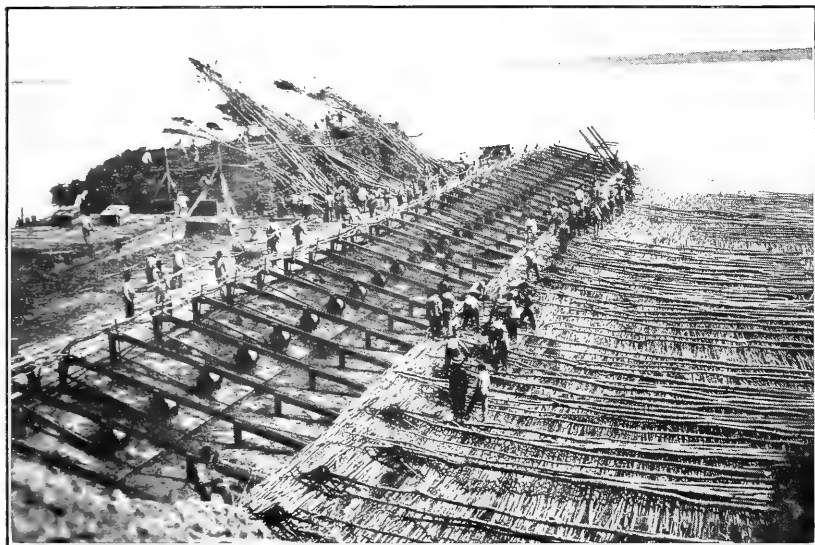
The plentiful supply of willows has heretofore made their cost simply that of cutting and transporting them. In the last few years, however, the willows in the immediate vicinity of some of the larger revetment works have become so scarce that from \$1 to \$2 per acre has been paid for the privilege of cutting over private lands. The best willows come from the lower sand bars and islands. Willows growing above the 35-foot stage of the river are seldom used, both on account of the expense of getting them to the water and the fact that they are seldom of the right quality, being generally crooked and

branchy. In 1913 the contractors received \$1.50 to \$2 per cord for the willows loaded on barges, and at this price they were in some instances able to make wagon hauls of a mile and still operate at a profit.

The first cutting is sometimes 10 or 12 years old, although willows 8 or 9 years old are most commonly used. On cut-over land the new crop is ready in 7 years, and in several places in lower Missouri three crops including the original seedlings have been grown and cut off in 25 years' time. The average yield of fully stocked stands (and most of the stands are fully stocked) is 40 cords per acre, although it may range 10 cords above or below this figure on small areas. The original seedlings at this rate produce an average of 4 cords per acre per annum; and the sprout growth, between 5 and 6 cords per acre per annum. These figures represent the maximum capacity of the land, complete utilization, and a low solid content per cord. It is doubtful whether the trees at this age reach their maximum production, but the increased production obtained by a longer rotation would be offset by the less close utilization that would be necessary if the material went into cordwood for excelsior, pulp, or fuel.

The land on which these willows are found is usually a rich sandy silt, although here and there occur patches of less fertile sands on which the growth is not so vigorous. This land, fertilized by a deposit of sediment each year, is rich enough to produce a relatively high yield of any kind of crop if it could be farmed. On poorer land, even if moisture conditions were favorable, it is doubtful whether more than one-half to two-thirds of this yield could be obtained.

The use of willows by the Army engineers has so far been for the manufacture of channel, pocket, and facine mattresses. To make these mats, they have developed especially built machinery and barges, so that in recent years the cost has been much reduced. The mats are usually 1,000 feet long, 250 feet wide, and 12 to 14 inches thick. The dimensions, however, vary considerably in accordance with the requirements of the situation. After sinking the mat along the bank, the upper portion approximately at low-water mark, the bank is graded with a hydraulic grader to a slope of 1 to 3 and paved with rock varying in size from 4 to 100 pounds. (See Pl. VII, fig. 2.) The cost of making the mat varies considerably, but on the average is from \$4 to \$8 per square (a square is 100 square feet), or \$10 to \$20 per linear foot. The completed work, including the mattress, grading, and paving, costs \$20 to \$30 per linear foot. The mats will last for 30 years, or longer under favorable conditions. Portions of the mat exposed at intervals of low water have a tendency to disintegrate very quickly unless buried



F-16782A

FIG. 1.—WEAVING A WILLOW MAT. SLOUGH NECK LANDING, TENN.



F-16785A

FIG. 2.—REDUCING THE BANK TO THE PROPER GRADE WITH THE HYDRAULIC GRADER.
SLOUGH NECK LANDING, TENN.

BANK-REVTMENT WORK.



F-16787A

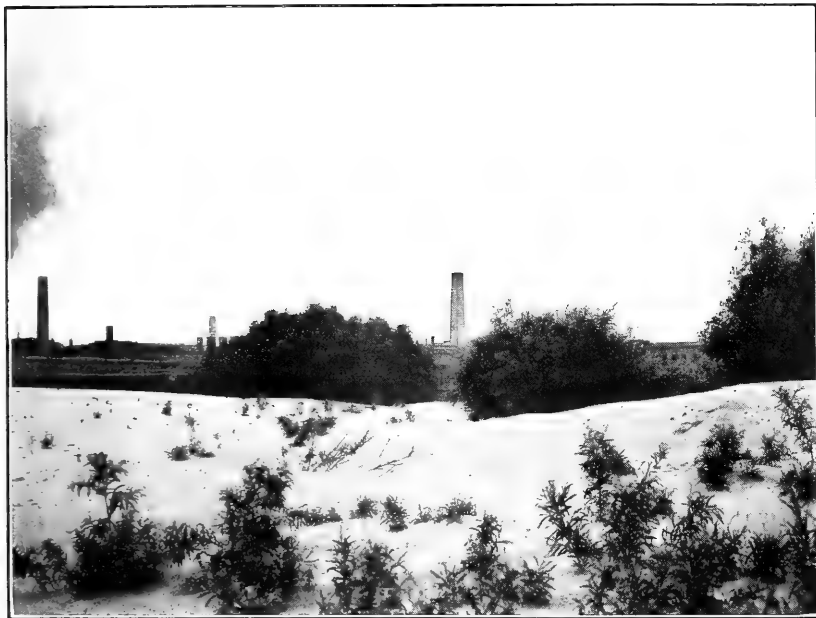
FIG. 1.—THE MAT AS IT NEARS COMPLETION, 1,000 FEET LONG AND 250 FEET WIDE.



F-16792A

FIG. 2.—SINKING THE MAT BY THROWING ROCK BALLAST ON IT.

BANK-REVTMENT WORK.



F-38260

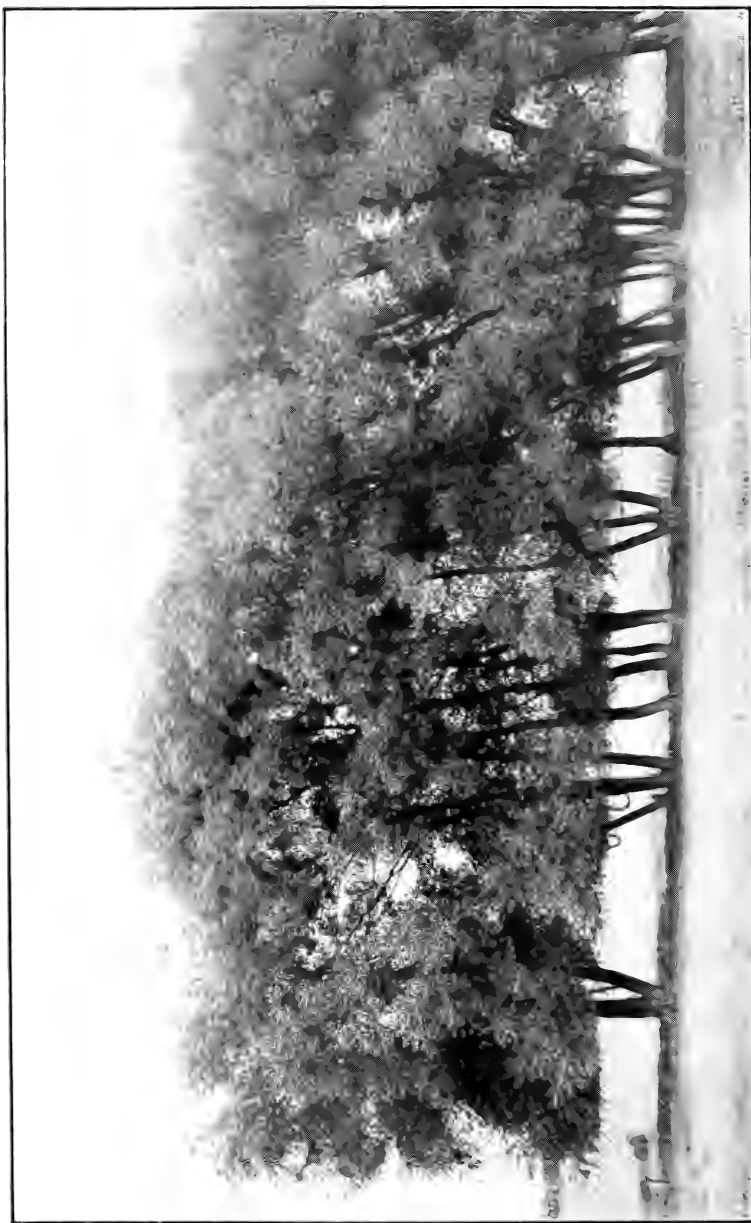
FIG. 1.—WILLOWS COMING IN NATURALLY AND GRADUALLY BINDING TOGETHER THE SHIFTING SAND DUNE. NEAR MICHIGAN CITY IND.



F-38301

FIG. 2.—WILLOWS AND POPLARS WORKING DOWN TO THE EDGE OF LAKE MICHIGAN. MICHIGAN CITY, IND.

WILLOW AS A SAND BINDER.



P-16114A

TYPICAL WILLOW ROW IN PASTURE. DENSE FOLIAGE ABOVE REACH OF STOCK. CRACK WILLOW. AGE 30 YEARS. WILLIAMS-BURG, IOWA, 1913.

in the mud and sand. In sinking the mat into position stone is used. This process is shown in Plate VIII, figure 2.

Table 17 shows, as near as it is possible to obtain the figures, the annual amount of willow used in revetment work. Where annual figures are not available, the average amount used for several years is given. Approximately 5 per cent of the amount is cottonwood or other species.

TABLE 17.—*Amount of willow used in revetment work.*

	Cords.
Missouri to Ohio River, average of 3 years.....	25, 000
Missouri River, Fort Benton to Kansas City, 1913.....	12, 000
Missouri River, Kansas City to mouth, 1913.....	43, 580
Mississippi River, St. Paul, Minn., to Missouri River, average of 4 years....	100, 000
Mississippi River, Cairo, Ill., to White River, Ark., 1913.....	48, 360
Mississippi River, White River to Warrington, Miss., 1913.....	51, 633
Mississippi River, Warrington, Miss., to Head of Passes, 1913.....	53, 350
Mississippi River, South and Southwest Passes, average of 4 years.....	23, 330
Arkansas and White Rivers.....	900
Total.....	358, 153

WILLOW AS A SAND BINDER.

One of the most important uses of willows is for binding shifting sand. Along the Atlantic coast and the Great Lakes, and to a lesser extent along the Pacific coast, there are large areas which are being reclaimed or will be reclaimed as land becomes more valuable. On the eastern shore of Lake Michigan considerable work has been done and more should be undertaken, as the dunes are moving in in many places and covering valuable farm land. Plate IX shows a dune being reclaimed naturally by willows and an older portion where poplar has followed the willows. Ordinarily it is customary to start grass first in such places, but where conditions are favorable willows can be started without this preliminary step. In Russia large areas have been reclaimed, principally by means of the Caspian willow (*Salix acutifolia*). The willow is very successful where brush is available and can be scattered over the sand areas as a temporary shelter under which it may gain a foothold before being subjected to the full force of the wind. On the Pacific coast loose straw was thrown on the land, and although the wind was very strong a surprisingly large amount was not blown away. Such a planting, however, to be effective must begin on the lee side of a body of water or strip of timber or some object that prevents the blowing of the sand upon the planting to any appreciable extent. Planting begun in this way can be continued out over the shifting area indefinitely with little chance of failure. It is, however, worse than useless to attempt to plant up an area which has adjacent to it on the windward side a body of loose sand.

The native species are best adapted to this purpose. In all the regions mentioned there are to be found growing wild, even upon the sand, willows with which better success can be had than with imported species. The basket willow can not be recommended for this purpose, although in the less exposed and more fertile places they would perhaps grow very well. The white, crack, and yellow willows make a very thrifty growth in the sand where conditions are not too severe. Of the native species the black willow, the sandbar willow, and the laurel willow grow well in such situations.

The cuttings should be from 12 to 18 inches long, the length depending somewhat on how much the sand dries out during the dry season. The rows should be run perpendicular to the direction of the prevailing winds, and from 6 to 12 feet apart, the distance depending upon the slope and the intensity of the wind. The steeper the slope the closer the rows should be. The cuttings should be planted in the rows and as closely as possible.

WINDBREAKS AND SHELTER BELTS.

For windbreaks and shelter belts in the central prairie States there has been no more widely used tree than willow. When the settlers came into these States they immediately saw the necessity of providing shelter around the farm buildings and planted such quick-growing species as willow, cottonwood, and soft maple, willow predominating. The stock was easily obtained, easily planted and required the minimum of care. The returns from these plantations have been good considering the treatment given them. Many are now dead or decadent and the question is what to do next. The wise settlers have underplanted their willow groves or started other species to replace them. The majority, however, overlooked this important matter.

For starting a grove or windbreak in the prairie region there is probably no better tree than the willow. It grows rapidly, is fairly long lived except on dry clay soils, has a fuel value on the farm, and reproduces vigorously from the stump. The green ash or white elm are more valuable, but generally should follow the willow on a barren farm. Cottonwood as a windbreak or as a nurse tree is no better than willow, but occasionally even on the prairies it produces a fair grade of rough lumber, perhaps better than willow. Because of its branching habit, its lack of clear length until the tree becomes quite large, and its fairly heavy foliage the willow is not surpassed by any other broadleaf tree in the protection afforded. Willows can also be thinned heavily with the assurance that sprout reproduction will rapidly take the place of the material cut out. In fact, such thinning is beneficial to the windbreak, as the foliage is kept low and dense, and cutting back will often keep the row vigorous for from 40 to 50

years, whereas if the cutting is not done each plant develops one to three large trunks which in from 20 to 30 years reach maturity or are broken, the vigor of the original tree being thus practically destroyed. The capacity of a willow tree to put out vigorous sprouts begins to decline somewhat at the age of from 20 to 30 years, depending upon the soil and moisture conditions, but it never entirely passes away. If the willows are to be considered permanent, they should be cropped in periods of 8 to 10 years, either by gradual or clear cutting. At the first evidence of decreasing vigor new trees should be set out and the first ones cut as soon as the second planting is large enough to be effective. Ordinarily the willows should be considered a temporary shelter or a nurse crop and provision made for the establishment of conifers or of the better hardwoods to take their place.

PLANTING WILLOWS.

SOIL REQUIREMENTS FOR WILLOW PLANTING.

Willows grow best on a moist, rich, well-drained sandy loam. They will, however, tolerate a considerable variation of these conditions and still make a reasonably satisfactory growth. They will grow faster for the first 25 years than any other of the northern broadleaf species, with the exception of cottonwood, on any but the driest soil. They endure excessive moisture conditions better than cottonwood. Willows are not sensitive either to acid or alkaline soils, but a poor growth can be expected on soils where either of these conditions is very pronounced. Willows prefer land that is flat or nearly so, but they grow well on any slope where the other conditions are favorable. The adaptability of willows makes them particularly a waste-land species, but their greatest superiority shows itself in plantations on overflow land in the vicinity of streams.

SPECIES FOR PLANTING.

In the North undoubtedly the best willow species for planting is the crack willow. Its rapid growth, upright form, and freedom from side branches or water sprouts when fairly closely planted make it superior to every other. Many plantations in the treeless region have been of this species, although generally reported as white willow. The second best species is the white or yellow willow. In sheltered positions the weeping willow will grow almost as fast as the crack willow, but if exposed will be broken up by the wind at an early age. While it is possible for the weeping willow to produce almost as much fuel as the crack willow, the form of the tree makes the material it produces of little value for anything else. The weeping willow recommends itself over the crack willow only for situations where its particularly striking and beautiful foliage can be made

effective in the improvement of the landscape. Throughout the North the black willow is a smaller tree than the white or crack willow, and for this reason inferior to them. As a tree for planting it is not recommended except in places where the main consideration is the protection to be afforded, rather than the material produced. Under these conditions the black willow is very desirable, as it can usually be secured in the vicinity at little cost.

In the South the same recommendations hold good except for black willow. The lower Mississippi Valley is the region of best development of this species, and its rapid growth and large size make it doubtful whether either crack or white willow would be superior to it. No records of the growth of crack or white willow in the region are available, and until they are preference should be given in planting to the black willow, at least on bottom land.

CUTTINGS.

MATERIAL.

Willows are more easily planted than any of the other commercial tree species of the United States. This is due to the fact that cuttings can be gathered and planted as cheaply as seed of most species, and the first year's growth of cuttings is equal in vigor to that of 1-year-old seedlings. As compared with 1-year-old seedlings, cuttings are much less expensive. Cottonwood can also be propagated by cuttings, but they are generally less easily secured wild, are more expensive if purchased, and unless rooted or calloused suffer a much greater mortality when planted. Under unfavorable conditions uncalledous willow cuttings will start where cottonwood fails completely. Willow cuttings can be obtained for \$1 to \$1.50 per thousand. When large quantities of cuttings are desired and there is no particular hurry about getting them planted, a few cuttings planted in a row in the garden will supply the necessary planting material. The Forest Service furnishes a list of dealers from whom willow cuttings may be purchased.

SIZE OF CUTTINGS.

The cuttings should be obtained from healthy, vigorous plants, the size of the cutting depending upon the kind of crop desired and the conditions under which it is to be grown. If the plants must establish themselves in competition with other species, such as scrubby willows, the cuttings should be larger than where the plantation is to receive cultivation. In open spaces, especially those which can be cultivated for a year or two, cuttings of a foot in length can be used to advantage, and these after the first or second year will be abundantly able to take care of themselves, although cultivation for a longer period, if it could be done economically, would increase the growth consider-

ably. In general the smaller the cutting, if protected from mechanical injury, the less chance for disease. The best size for average conditions is about 16 to 20 inches long and from one-half inch to 1½ inches diameter. In the method known as "pollarding," sometimes employed in willow growing, the cuttings are made 8 to 10 feet long and from 1 inch to 3 inches in diameter from branches or shoots ranging in age from 3 to 5 years. These at the end of the first season present the appearance of a small tree with an 8-foot clear length, and when planted under unfavorable conditions are much more able to compete successfully with other species. However, this high-coppice system has its drawbacks. Such plants with a strong growth of sprouts produced 8 feet from the ground on a poorly rooted trunk give an excellent opportunity for serious injury. The wind alone is often sufficient to sway it enough to break the small new root system. If this occurs in the middle or the latter part of the growing season, it generally kills the plant. There are certain conditions, however, that may make the pollard system advisable. When the trees are to be planted in situations where they are likely to be periodically inundated, it may be better to have the limbs produced above the reach of the flood if there is no débris or ice to cause serious injury to the trunk. Where animals must be allowed to graze on the land it is better to have the sprouts above their reach, as they not only browse the tender branches but do further damage by tramping and breaking off the limbs. High coppice is also desirable where the land is to be cultivated between the rows of willows, as the production of a sprout growth from the ground would take up so much room that there could be no economy in growing the two crops together. This is the chief reason why pollarding is resorted to in many parts of Europe. Such a crop practice is little used, however, in this country.

The low coppice has the important advantage that it gives a chance for the individual sprouts, especially if they come from the region of the root collar, to form roots of their own so that the life and health of the sprout is not necessarily dependent upon the old trunk. It has been observed that in many instances where a low coppice system has been employed the original trunk has completely decayed but the surrounding sprouts have formed root systems of their own, from which they receive support and nourishment. Low coppice makes possible an indefinite regeneration of the tree, while the high coppice requires periodic plantings.

AGE OF CUTTINGS.

The cuttings should always be made from young, vigorously growing wood. If old wood is used a smaller number of the cuttings will start and the growth at first will be less rapid. The cuttings from old wood do not start as quickly after planting as do those from young

shoots. The reason for this is that on 2-year-old sprouts there are frequent buds ready to start growth at once, while on older wood the buds and shoots must start after the cutting has been planted and the growing season has commenced. Another advantage of the young sprout is that it is generally free from branches and thus easier to prepare and plant. Under less favorable conditions it is necessary to use cuttings from 2 to 5 years old. When it is known that willow cuttings are to be used the following year, it is a good plan to cut off limbs of small trees the year before in order that suitable material for planting may be produced. A little forethought in this matter will often make the purchase of material from dealers unnecessary, although the grower should make sure that he is planting the right species.

TIME AND METHOD OF MAKING CUTTINGS.

The cuttings can be prepared any time after the wood is well ripened in the fall, but in the Northern States the best time is in February, as this gives the cuttings a chance to callous before being set out and at the same time does not necessitate leaving them in storage long enough to become damaged. Cutting can be done with a large knife, a hatchet, a saw and miter box, or with large pruning shears. The cutting should be made smooth and clean. The small saw and miter box is a very rapid method but is likely to tear the bark from the wood, thus injuring the cutting. With a large pruner several sprouts can be cut at once without crushing the bark unless the sprouts are resting on top of each other. In the preparation of larger cuttings an ax or saw must be employed. The ax is preferable. It is best to plant large cuttings as soon as prepared, as they are not easily stored.

STORAGE AND SHIPMENT.

It is often advisable to prepare cuttings a considerable length of time before they can be planted. In such a case it is necessary to provide a suitable place for storing them. A cool dark cellar is ideal for this purpose, since at all times of the year growth is less likely to start there than in other places. The cuttings should be buried in an upright position (the buds pointing upward) in moist sand. Moist earth can be used, but it is not so satisfactory as sand. When no other place is available, cuttings can be heeled-in in pits in the open. The top of the pit should always be covered. Cuttings stored in this manner are likely to start early in the spring, and for this reason they should be carefully watched.

METHOD OF PLANTING.

In establishing a plantation of willows the amount of preparation to be bestowed upon the land is dependent upon its condition. Land well situated and free from other woody plants and rocks should

be thoroughly plowed. If this can not be done and the cuttings must be planted among bowlders, among other trees, or in brush, clear spaces should be selected wherever possible or the brush should be lopped back in order to give the cuttings a chance to start. Once started, the willows soon outstrip the brush and eventually kill it by shading.

All planting should be done in early spring. How deep cuttings should be planted depends somewhat on their size. In planting for low coppice crops, a 12-inch cutting should be buried almost its entire length, leaving but 1 or 2 inches exposed. This portion should possess one or two buds. When longer cuttings are used, the depth should be 12 to 15 inches. Pollard sets should be planted about 18 inches deep. For making the holes to plant small cuttings a sharpened iron bar may be used, but for the larger cuttings a spade is necessary. In every case the soil should be packed firmly around the cutting.

The spacing of the cuttings is dependent upon the kind of land to be used and the crop desired. If the land is clear, a regular interval can be employed, but on steep slopes and among brushy or rocky obstructions it is better to plant wherever a favorable spot can be found or made. If a regular interval is employed and lumber is desired, the cuttings are planted 6 by 6 feet or 1,210 plants per acre. Thinnings are made at the end of 8 or 9 years, reducing trees to half the original number, and at the end of 16 or 20 years, reducing the number of trees to about 300 per acre. The material taken out can be used for charcoal wood or for fuel. At the end of 30 or 40 years the land should be stocked with at least 150 trees, most of them of suitable size and shape for willow lumber. However, the majority of willow plantations in this country will be intended for fuel, paper pulp, or posts, and for these purposes it is better to plant about 5 by 5 for a 6 to 10 year rotation and 6 by 6 or 8 by 8 for a 12 to 20 year rotation.

COST OF PLANTING.

Under most conditions willow plantations can be established more cheaply than plantations of any other species. Cuttings are used in all cases. It is well to prepare the land before planting by a thorough plowing, disking, and harrowing. This costs from \$1.50 to \$3 per acre. If the land is pasture land or an abandoned field, some work in brush or tree removal is often necessary. This costs up to \$3 per acre. If a greater expense than this is necessary it is advisable to clear the land for plowing. In such cases it is best to destroy the brush cheaply, by burning, for instance, and then planting in spots wherever possible. By this procedure the cost of plowing is eliminated but the cost of planting is correspondingly increased. Cuttings for planting can be made for 50 cents per thousand and can be

purchased for \$1 to \$1.50 per thousand. Planting is best done by a man and a boy. If the man makes the holes with a sharpened iron bar and the boy drops in the cuttings and firms the soil, they should plant 2 to 3 acres per day with a spacing of 6 by 6 feet, or 1,210 sets per acre. Allowing \$2 as wages for the man and \$1 for the boy, the cost of planting is from \$1 to \$1.50 per acre. Cultivation for the first two years consists in disengaging the willows in the planting spots on unplowed land and in horse cultivation on plowed land. This costs from \$2 to \$6. Table 18 gives the range in cost of establishment of a willow plantation.

TABLE 18.—*Cost per acre of making a willow plantation.*

	Minimum.	Maximum.
Preparation of soil:		
Brush clearing.....		\$3.00
Plowing or preparation of planting spots.....	\$1.50	3.00
Stock (cuttings).....	.50	1.50
Planting (man and boy crew).....	1.00	1.50
Cultivation (first two years).....	2.00	6.00
Total.....	5.00	15.00

CULTIVATION AND CARE.

If the plantation is a haphazard one, planted among boulders, stumps, or in uncleared land, it can not, of course, be systematically cultivated. However, a little care in such a place will probably pay better returns than anywhere else. The young plants are very likely to be crowded out the first year or two if they do not have a fair amount of room, and a little cutting back of other growth will often save many young trees. In regular plantations on cleared land the ground should be plowed between the rows about three times the first year, twice the second year, and perhaps once the third year. Subsequently the shade of the willows will be sufficient to kill most of the weeds and to prevent excessive evaporation from the soil. Cuttings which fail to start should be replaced the same season if possible. In close plantations it will be necessary to plant longer cuttings than the original ones to prevent shading out. Allowing the fail places to remain unplanted reduces the productivity of the land. All diseased material should be removed as soon as noted.

CUTTING.

The best time for cutting is in late winter or early spring, but it should be finished before the buds start to swell. Fall cutting is next best, but it may result in the frost separating the bark from the wood at the stump, which injures its ability to sprout. Wood that is to be peeled should be cut in summer. Where sprout reproduction is desired, the bark should be cut through around the stump, so that when the tree is felled the bark will not be torn away.

COST OF GROWING WILLOWS.

Table 19 gives the cost per cord of growing willows on land of different values, with different costs of formation, low, average, and high yields, and different rotations. In this table compound interest at 6 per cent is charged on the land value, the cost of formation, and taxes. With a cost of formation of only \$3 and a high yield the actual cost of growing a cord of willows on land valued at \$5 per acre is 20 cents. Such a combination of conditions is exceptional, however, and would rarely be encountered. A poor yield from land valued at \$100 and a cost of formation of \$15 makes the cost of growing a cord from \$5.95 to \$7.64, depending upon the rotation. Except where the wood lot has a decided value for other purposes than the wood crop itself the plantation is not justified by the returns. Leaving out every other consideration except the value of the material produced, it is poor business to grow willows when the cost is greater than \$2 per cord. This practically eliminates the use of \$100 land for such a purpose unless a yield of 5 cords per acre is assured.

TABLE 19.—*Cost per cord of growing willows.*

\$5 LAND.

Rotation— years.	Formation, \$3.			Formation, \$5.			Formation, \$7.50.			Formation, \$10.			Formation, \$15.		
	Yield in cords.														
	5	3½	2	5	3½	2	5	3½	2	5	3½	2	5	3½	2
5.....	\$0.24	\$0.34	\$0.60	\$0.35	\$0.49	\$0.87	\$0.48	\$0.69	\$1.20	\$0.61	\$0.88	\$1.54	\$0.88	\$1.26	\$2.20
10.....	.20	.29	.50	.27	.39	.68	.36	.52	.90	.45	.64	1.13	.63	.90	1.57
15.....	.20	.29	.51	.27	.38	.67	.35	.50	.87	.43	.61	1.07	.59	.84	1.47
20.....	.22	.32	.56	.29	.41	.72	.37	.53	.92	.45	.64	1.12	.61	.87	1.52

\$10 LAND.

5.....	\$0.32	\$0.45	\$0.80	\$0.43	\$0.61	\$1.06	\$0.56	\$0.80	\$1.40	\$0.69	\$0.99	\$1.73	\$0.96	\$1.37	\$2.40
10.....	.29	.42	.73	.36	.52	.91	.45	.65	1.13	.54	.78	1.36	.72	1.03	1.80
15.....	.31	.45	.78	.38	.54	.94	.46	.65	1.14	.54	.77	1.34	.70	1.00	1.74
20.....	.35	.51	.88	.42	.60	1.04	.50	.71	1.24	.58	.83	1.45	.74	1.06	1.85

\$25 LAND.

5.....	\$0.55	\$0.79	\$1.39	\$0.66	\$0.95	\$1.66	\$0.80	\$1.14	\$1.99	\$0.93	\$1.33	\$2.32	\$1.20	\$1.71	\$2.99
10.....	.57	.81	1.42	.64	.91	1.60	.73	1.04	1.82	.82	1.17	2.05	1.00	1.43	2.50
15.....	.64	.91	1.60	.70	1.00	1.76	.78	1.12	1.96	.86	1.23	2.16	1.02	1.46	2.56
20.....	.74	1.06	1.85	.80	1.15	2.01	.88	1.26	2.21	.96	1.38	2.41	1.12	1.61	2.81

\$50 LAND.

5.....	\$0.95	\$1.36	\$2.37	\$1.06	\$1.51	\$2.64	\$1.19	\$1.70	\$2.98	\$1.32	\$1.89	\$3.31	\$1.59	\$2.27	\$3.98
10.....	1.03	1.47	2.58	1.10	1.57	2.75	1.19	1.70	2.98	1.28	1.83	3.20	1.46	2.09	3.65
15.....	1.18	1.69	2.96	1.25	1.78	3.12	1.33	1.89	3.31	1.41	2.01	3.51	1.57	2.24	3.91
20.....	1.38	1.98	3.46	1.45	2.07	3.62	1.53	2.18	3.82	1.61	2.30	4.02	1.77	2.53	4.42

\$100 LAND.

5.....	\$1.74	\$2.48	\$4.35	\$1.85	\$2.64	\$4.62	\$1.98	\$2.83	\$4.95	\$2.11	\$3.02	\$5.28	\$2.38	\$3.40	\$5.95
10.....	1.95	2.79	4.88	2.02	2.89	5.06	2.11	3.02	5.28	2.20	3.15	5.51	2.38	3.40	5.96
15.....	2.27	3.24	5.67	2.33	3.33	5.83	2.41	3.45	6.03	2.49	3.56	6.23	2.65	3.79	6.63
20.....	2.67	3.82	6.68	2.74	3.91	6.84	2.82	4.02	7.04	2.90	4.14	7.24	3.06	4.37	7.64

In certain localities where there is a market for willow for gunpowder charcoal, or as excelsior wood, it would be profitable to grow willow when the cost of growing is \$4 or under, since cut and peeled it is worth \$7 per cord. Willow cordwood for fuel is not worth more than \$4 in the prairie States, and as cutting costs \$1.50 per cord \$2.50 is the greatest cost allowable if a return of 6 per cent is to be received on the money invested. Under the conditions that have prevailed in the Middle West, where most of the willow plantations have been made, the average cost of growing has been from 50 cents to \$1.50 per cord, estimated on the value of the land at the time of planting. To-day higher land values in this section of the country and higher costs make the probable average cost about \$1.50 per cord. It should still be possible, however, to grow willows at \$1 per cord on \$25 land.

Many other considerations enter into the problem of determining whether or not it may be profitable to grow a tree crop on the farm besides the mere cost of growing the wood. The chief of these is the possibility of using labor at slack times. This may be worth more than the loss of 6 per cent on capital invested in the land. The value of the woodlot for protection and appearance must also be considered.

YIELD FROM WILLOW PLANTATIONS.

The yield from willow plantations varies greatly with the soil and moisture conditions and the care they have received. Planted on moist, well-drained bottom lands and kept free from the grazing of stock, willows will sometimes yields over 5 cords per acre. On short rotations where several crops are grown from sprouts the yield may, under exceptional conditions, reach 7 cords per acre per year. The average bottom-land plantation in which stock is allowed to run can not be expected to yield more than 4 cords per acre except on the most fertile soils. Willows planted in rows give slightly larger yields than in other plantations, even when due allowance is made for all the ground they cover. On an average they yield 20 per cent more than in a dense stand. This is no doubt due to the greater amount of light received on a given unit of space.

In the more moist situations on upland soil willows make a fairly good growth, and a return of 3 cords per acre from a well-managed plantation can reasonably be expected. On the dry situations the yield is not over 2 cords per acre. Willow plantations on upland soils show very quickly the bad effects of grazing, especially in the more open stands. In such plantations the yield is seldom more than 1½ cords per acre.

Table 20 gives the yields of average sample plots, the kinds of material, and its value for plantations in the Northern States. These groves were not selected and represent minimum returns rather than average returns.

TABLE 20.— *Yield and gross returns from crack willow plantations.*

UPLAND.

Locality.	Age of Grove.	Aver- age height of trees.	Area of plot.	Num- ber of trees per acre.	Total yield per acre.	Estimated in cordwood.				Estimated in posts, stakes, and cords.								Value of posts and ad- ditional cord- wood.	Cost of forma- tion.	Net an- nual gain.
						Total yield per acre.	Aver- age annual yield per acre.	Total value per acre at \$4.	Aver- age annual value per acre at \$4.	First-class posts 4 to 6 inches.		Second-class posts 3 to 4 inches.		Stakes 2 to 3 inches.		Cords in ad- dition.				
										Num- ber.	Value at 12 cents.	Num- ber.	Value at 8 cents.	Num- ber.	Value at 5 cents.	Num- ber.	Value at \$5.			
Conde, S. Dak... Elrod, S. Dak... Warren, Minn... Averages...	Y'ears.	F'et.	A'cres.		Cords.	Cords.														
	13	30	0.1	1,920	20.96	1.61	\$83.84	\$6.45	1,390	\$166.80	890	\$71.20	1,430	\$71.50	6.50	\$32.50	\$20.88			
	20	39	.1	1,510	34.50	1.73	138.00	6.90	1,390	63.60	1,190	95.20	1,310	65.50	5.30	26.50	23.08			
	21	30	.1	760	36.00	1.71	144.00	6.86	530		2,200	176.00	2,190	109.50	9.20	46.50	26.45			
						1.68												11.62		

BOTTOM LAND.

Milnor, N. Dak....	8	28	0.1	3,520	1,650.00	23.70	\$94.80	\$11.85	3,870	\$464.40			3,300	\$105.00	10.60	\$53.00	\$218.00	\$18.01	\$22.49
Groton, S. Dak....	18	45	.1	1,290	4,857.50	60.99	243.96	13.55	9,420	1,130.40	2,340	\$187.20	3,480	174.00	4.47	22.35	551.25	24.21	22.51
Carby, Minn. ¹	20	53	.05	2,340	11,703.20	144.60	578.40	28.92	2,900	348.00	1,450	116.00			3.80	19.00	1,510.60	25.68	55.26
Grafton, N. Dak....	20	42	.1	725	3,958.50	49.50	198.00	9.90	2,270	272.40	920	73.60	470	23.50	8.00	40.00	504.00	25.68	17.80
Tea, S. Dak....	21	43	.1	1,330	3,637.70	47.50	190.00	9.05	4,140	496.80	2,940	235.20	1,120	56.00	4.10	20.50	390.00	26.45	12.67
Cottonwood, Minn....	22	44	.1	2,280	6,833.40	88.40	353.00	16.07	3,620	344.40	1,960	156.80	810	40.50	3.80	19.00	807.00	27.25	25.53
Hatton, N. Dak....	23	52	.1	1,310	5,403.20	68.00	272.00	11.83	3,730	447.60	960	76.80	1,180	59.00	5.20	26.00	637.70	28.06	19.40
Volin, S. Dak....	24	56	.1	1,840	4,049.90	51.20	204.80	8.53							2.20	11.00	594.40	28.91	16.43
Averages....						3.42													24.01

¹ In this grove no thinnings had been made, and the plot included an outside row.

The returns from willows planted now may be more fairly estimated on the basis of what the best plantations of the past have done rather than the averages, because the average plantations represent a great amount of poor practice that may now be avoided. The following yields are for groves whose appearance and history show that they have been treated in a rational manner:

TABLE 21.—*Yield of selected willow groves in Iowa.*

Plot No.	Size of plot.	Age.	Yield per acre.	Yield per acre per year.	Location.
	<i>Acres.</i>	<i>Years.</i>	<i>Cords.</i>	<i>Cords.</i>	
1.....	0.25	11	47.3	4.3	Bottom land.
2.....	.25	16	76.8	4.8	Do.
3.....	.25	16	62.4	3.9	Do.
4.....	.25	18	109.8	6.1	Do.
5.....	.25	18	81.0	4.5	Do.
6.....	.25	21	109.2	5.2	Do.
7.....	.25	21	73.5	3.5	Do.
8 ¹	.25	22	116.6	5.3	Do.
9.....	.25	24	132.0	5.5	Do.
10.....	.25	25	105.0	4.2	Upland.
11.....	.25	25	95.0	3.8	Do.
12.....	.25	31	102.0	3.3	Do.
Average.....				4.5	

¹ Illinois Agricultural Experiment Station.

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LARCH MISTLETOE: SOME ECONOMIC CONSIDERATIONS OF ITS INJURIOUS EFFECTS.¹

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INTRODUCTION.

During the past four years, in connection with other pathological problems in the forest, the writer has made an extensive survey of the damage to forest growth by some of the mistletoes of coniferous trees. These parasites are very widely distributed in the forest regions of the Northwest, and occur in such abundance in many localities as to assume a very serious aspect in relation to many forest problems. The extent and nature of the injury done vary greatly with the forest type, the topography, and, in some respects, with the climate. This is well shown in the regions in which investigations are now being conducted. In the dense part of many forest regions, as in the vicinity of the great lakes of Idaho, mistletoe does but little damage. However, in the more open stands bordering on the lakes or along the edge of the valleys of the Priest and Pend Oreille Rivers mistletoe occurs so abundantly on the various conifers as to interfere seriously with the development of some of the more valuable timber trees. About the shores of Lake Coeur d'Alene,

¹ The writer wishes to express his thanks to Mr. J. F. Pernot, without whose assistance the analysis of the trees would have been difficult, and to Mr. E. E. Hubert for assistance in the tabulations.

along the Spokane River Valley, and extending to the south into the Blue Mountains of Washington and Oregon the mistletoes are very abundant, especially on lodgepole pine (*Pinus contorta*), yellow pine (*Pinus ponderosa*), western larch (*Larix occidentalis*), and Douglas fir (*Pseudotsuga taxifolia*). In many localities the trees rapidly yield to the suppressing effects of these parasites, causing an open, ragged growth of the crowns, with the production of many brooms. The prevalence of a particular species of mistletoe varies greatly in the same general region. To illustrate: Along the hills fronting on the Pend Oreille River, Idaho, the lodgepole and yellow pine stands are heavily infected. Passing up the Priest River Valley, another mistletoe species appears, working considerable injury to the larch, whereas the same tree, wherever it occurs along the Pend Oreille River, is seldom infected. The yellow pine farther up in the Priest River Valley is not seriously attacked. In the Granite Creek drainage area and beyond the mountains to Sullivan Lake, in the Metaline Falls region of Washington, the larch is again very seriously infected, whereas this mistletoe seldom occurs on the divide between these points. The western hemlock (*Tsuga heterophylla*) in the forests of northern Idaho is practically free from mistletoe, as far as the observations have been carried. In a few of the more open valleys several collections of mistletoe have been made from this tree. At many points in Washington and British Columbia where the writer has had an opportunity to collect, the mistletoe on the hemlock seems more abundant. Numerous collections of mistletoes are at hand from many of the forests of southern Montana, and likewise from the northern part of that State and from central Idaho. A trip through Oregon, Washington, and British Columbia during 1913 yielded much information on the occurrence of mistletoes in those localities, so that it will soon be possible, with the additional data now (1915) being collected, to give a fairly detailed statement of the range of these parasites in the principal forest regions of the Northwest.

In order to obtain reliable figures on the damage to forest growth by these plants, special studies of a directly practical nature are now being conducted in several of the most important forests of the regions indicated. It is believed that the results from these studies will be applicable to all the forest areas of the Northwest where trees of the same species are found infected by the same mistletoe. At the same time, work of an experimental nature, both in the field and in the laboratory, is adding to our knowledge of these parasites. This work is being continued, as having a practical bearing on the mistletoe problem, and will be reported upon as time and occasion permit.

THE LARCH MISTLETOE.

This bulletin deals in the main with the immediate practical results of an investigation of the injurious effects of the larch mistletoe on its host in the Blue Mountain region of Oregon and serves to introduce one of a series of studies on the mistletoes of coniferous trees in general. The larch mistletoe (fig. 1), originally named *Razoumofskyia douglasii laricis* by Piper¹ and given as a subspecies of the Douglas-fir mistletoe, has recently been raised by the same writer² to the rank of a full species under the following name and description:

Razoumofskyia laricis Piper. Pistillate plants olivaceous, clustered, 5-8 cm. long, branched; joints 1.5-2 mm. thick, sharply 4 angled; staminate swollen, yellow, the flowers in short spikes; lobes ovate, acute; fruit oblong, acutish, bluish, 4 mm. long. Common on *Larix occidentalis*.

The investigation was begun in the Whitman National Forest, Oreg. For some time the general and gradual deterioration of the western larch had been reported as occurring throughout the entire Blue Mountain region. The writer was not aware of the great prevalence of the larch mistletoe in this region until his visit there during the early spring of 1913. From a preliminary survey it soon developed that the primary cause of the deterioration of the larch resulted from the suppressing effects of mistletoe. A probable secondary factor on some of the more exposed sites seemed to be certain climatic influences unfavorable to the host but promoting the better development and spread of the parasite.

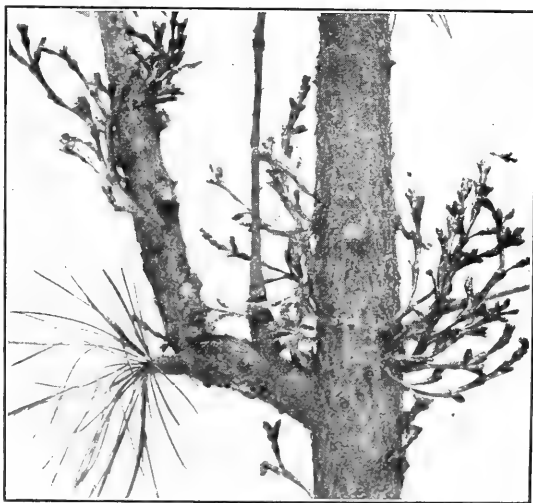


FIG. 1.—Staminate plants of *Razoumofskyia laricis*. Note the hypertrophy of the branch.

THE FOREST.

The Blue Mountains, in which further studies of the mistletoes are in progress, are well covered with forests. The yellow pine pre-

¹ Piper, C. V. Flora of the State of Washington. U. S. Nat. Mus., Contrib. Nat. Herbarium, v. 11, p. 222. 1906.

² Piper, C. V., and Beattie, R. K. Flora of Southeastern Washington and Adjacent Idaho, p. 80. Lancaster, Pa., 1914.

dominates as the principal tree on all the drier slopes and bench lands. This gives an open character to the forest and is of some significance as regards the growth of mistletoe on the larch wherever this tree is associated with the yellow pine. On the lower elevations the yellow pine often occurs in pure parklike stands, with a ground cover quite characteristic of the typical yellow-pine formation, usually indicated by the absence of any great amount of forest litter and by the uniformity and the small number of species of herbaceous and shrublike plants. On the south slopes and low, dry ridges, where the stand is very open, the yellow pine is quite generally infected with its particular mistletoe, working great injury to the tree. At higher elevations in more moist situations, or even at the same level on protected parts of the typical stand, the yellow pine becomes mixed with larch, Douglas fir, white fir, and lodgepole pine. The yellow pine gives way to greater percentages of larch, Douglas fir, and lodgepole pine on the north and east slopes. The two last-named species support large quantities of their respective mistletoes wherever the conditions are favorable for the development of these parasites. The larch predominates in many north-slope stands, especially in the more open situations. Other forest types in which the larch occurs above 6,500 feet or more are of little importance in this connection, since the species of the types at this elevation are not as seriously infected by mistletoe as those on north slopes of 5,000 feet altitude and less.

The influence of drainage, slope, and the general moisture conditions of the soil on the distribution and vigor of the western larch is well shown in the region studied and is likewise reflected in the prevalence and distribution of its principal parasite. Owing to the general prevailing dryness of the region, the maximum development of the larch is attained in moist draws or in fertile valleys not parallel with the direction of the prevailing winds. In such situations the tree is usually quite free from mistletoe, and uninfected trees often attain a diameter, breast high, of 60 inches or more. A full crown composed of the original branches is retained until late in life, the tree showing few defects except an occasional root-rot or a dead top occasioned by agents other than mistletoe. These situations are more favorable to the development of the host than to the mistletoe occasionally found upon it and must be considered the best sites for growing larch in these regions. On the drier slopes and benches, where the larch is associated more with yellow pine, the influence of the site on the vigor of the mistletoe is at once expressed by its greater abundance and its effects on its host, causing smaller diameters and thinner crowns on the infected trees. Occasionally trees in exactly similar situations for some reason escape the ravages of the mistletoe and attain a size of considerable proportions. The full

crown and degree of vigor shown by these trees late in life prove conclusively that the ragged, suppressed condition of their neighbors is not due wholly to unfavorable climatic or soil conditions, but to the effect of the mistletoe upon them.

On some north slopes where the larch is crowded by lodgepole pine and white fir it becomes suppressed for a time very early in life, as indicated by the zone of suppression in the older trees. Those trees finally escaping by their more rapid growth from the influence of their neighbors usually become infected by mistletoe when the crown spreads out to the light and air above. The opportunities for the mistletoe to attack suppressed trees with crowns overtopped by other species not subject to its ravages are not as great as when the trees are standing more in the open. This is due in part to the other species protecting the larch from seed falling on it, and in part to the fact that permanent tissue incapable of being penetrated by the primary sinker is more rapidly developed in the case of suppressed individuals. New growth is of short duration and fewer vulnerable points of easy infection exist. If the infection of the suppressed trees does occur and the infection succeeds for a time, the mistletoe plant may itself become suppressed, partly from a poor nutrient relationship with its host and partly through lack of light, and eventually may die without producing new infections higher up. The signs of old infections are frequently noted in the area of the zone of suppression in trees that have afterwards escaped from the crowding of their neighbors. If such trees again become infected later in life, they may attain a fair merchantable size before the influence of the parasite is made manifest.

PHYSICAL AND CLIMATIC FEATURES OF THE FOREST REGION.

The later geological history of the Blue Mountains, in which the Whitman National Forest is located, is one of a great basaltic uplift surrounding but not submerging the older granitic formations. The several high and low laterally arranged ridges are composed in the main of granitic rocks, forming a type of soil upon which the yellow pine usually becomes the climax species. Other soil characters induced by local variations of climate, slope, and type of ground cover influence the distribution of the forest trees of this region to a marked degree, and indirectly that of the mistletoe.

Summarizing the chief climatic characteristics of the region, compiled from the reports of the United States Weather Bureau, they are (1) scanty rainfall, (2) wide range of temperatures, (3) low absolute humidity, (4) rapid evaporation, and (5) an abundance of sunshine. The influence of such climatic conditions may be considered in general as unfavorable in a few localities to the best

development of the larch, but decidedly favorable to the mistletoe found upon it. This is at once evident to those familiar with the environmental requirements of host and parasite. The region affords a most instructive study of the advance and predominance of a forest-tree parasite on its host, showing this advance to be in as near an exact proportion as the conditions for its optimum development become more favorable.

The problem of the mistletoes in their ecological relationships, regardless of the fact that they are parasitic, is similar to that of all chlorophyllaceous plants: hence, they respond to light, gravity, and

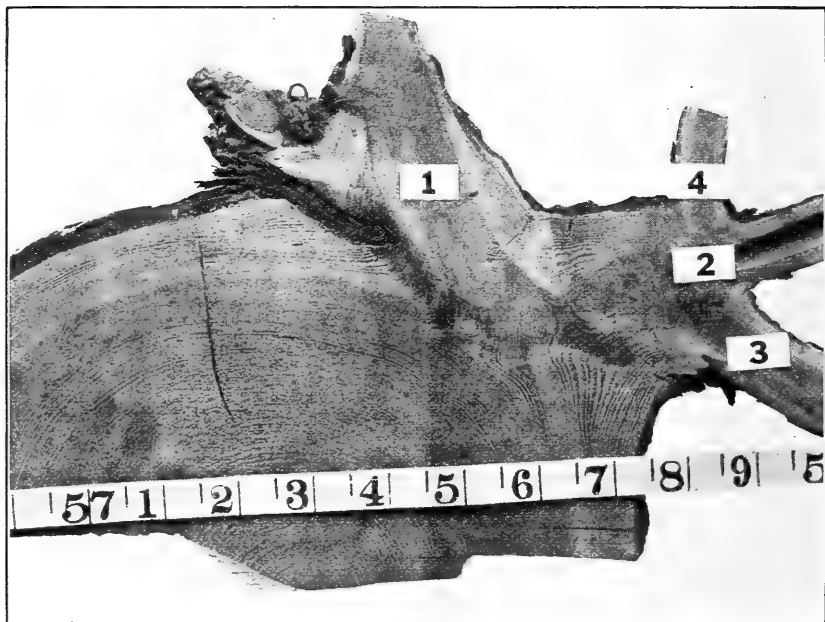


FIG. 2.—Cross section of a part of a trunk of a larch tree, showing the regeneration of branches from the same whorl to the fourth generation. (Tape in feet graduated in tenths.)

chemical influences, and in a far less degree to the influences of temperature and moisture. How, then, do the ecological requirements of the larch mistletoe hold with the climate of the region described, over which the parasite is widely distributed? The great variation in temperature, occasionally abnormally high, and the late, early, and winterkilling frosts of some sections, although seriously injuring the host, produce but little effect on the parasite. The uniform dryness of the air at all seasons of the year throughout the region does not greatly influence the mistletoe plant, which is essentially xerophytic. On the other hand, the large percentage of sunshiny days and the absence of clinging fogs are directly favorable to the parasite, as it is

positively phototropic. The possible influence of the low absolute humidity and rapid evaporation on the entrance of host, reproduction, etc., is counteracted by the parasite by means of special structures enabling it to withstand long periods of drought.

Probably no factor of the region so greatly aids the destructive effects of the mistletoe on the larch as the high, strong winds so prevalent in these mountains. The velocity of the winds is sometimes very great. During 1913 hundreds of reserved yellow pines on the sales area of the Whitman National Forest were uprooted. The wind in this case was materially aided by the insecure rooting of the trees on the surface of a hard stratum of rocks and gravel, together with a certain amount of decay in the brace roots. This is a condition often found in cases of this kind.

Strong winds probably do greater injury to the larch than to any other conifer. An examination of the branching or crown of a mature or middle-aged healthy larch will show that in most cases, especially in windy regions, the tree has been able to reach the standard size only through the production of several generations of branches replacing those broken off by the wind and by other causes (fig. 2). The loss of branches through crowding or natural pruning is not here considered. Trees standing under open conditions from the beginning will show this interesting phenomenon of regeneration. Increasing age, within a certain limit, on the part of the main trunk does not interfere with the anatomical and physiological connections of old branches. Consequently, branches forming at any age sufficiently high on the trunk to escape the influence of suppression should and would remain intact, barring all deteriorating influences, during the natural life of the tree.

Trees with wood exhibiting a natural brittleness, which is always very pronounced at the bases of branches, suffer greatly from breakage by the wind. The western larch is especially subject to this form of injury. The brittleness of its branches at their point of attachment with the main trunk is so pronounced that it is not un-



FIG. 3.—A larch tree of greatly reduced vigor caused by the formation of great witches'-brooms and the accumulation of dead leaves and lichens in them. Note that the tips of the branches, also the witches'-brooms in the upper portion of the crown, are dying.

common to find them lopped off by the wind. This is especially true of tall stems that have come up in close canopy and afterwards become more or less isolated. In the case of the larch the ill effects of the wind are greatly augmented by the heavy loads of long, trailing lichens (*Alectoria fremontii* Tuck. and *Usnea longissima* Ach.) supported by the branches (fig. 3). During rainy periods these lichens, through the absorption of large quantities of water, increase the weight of the branch by several pounds and, hanging downward in a saturated condition, offer a greater resistance to the wind. The



FIG. 4.—A larch, showing the original crown entirely removed by brooming. The secondary crown is also broomed. The witches'-brooms support large quantities of "black moss" (*Alectoria fremontii* Tuck.), which grows over and mats the foliar spurs.

amount of damage to the larch in many locations from this cause alone is much greater than is ordinarily supposed. In the study in the Whitman National Forest it developed that the injury to the larch by mistletoe (aside from the gradual effects of suppression by brooming up the branches and reducing the assimilatory surface) was in a large measure due to the pruning by the wind of the many branches which, being heavily loaded with witches'-brooms, caused an increased weight to be exerted at their bases. These brooms are often formed far out on the branch and become densely matted with dead leaves and lichens (fig. 3). This increase in weight often amounts to several pounds more than that of a normal branch of the same age and size (Table II) and is further increased by the absorption of water during rainy weather. In the winter the broom furnishes a collecting place for snow. It is very evident how the resultant of the two forces, viz, the wind in a lateral and the weight of the broom-laden branch in a vertical direction, may bring about the removal of all the main original branches (fig. 4). It is not uncommon to find large heaps of branches heavily loaded with brooms under the infected tree. Up to this point the breakage of normal wood uninfected by mistletoe roots has alone been considered.

The infected wood of the branch, either at its base or other portions, where not too greatly enlarged by the stimulating effects of the parasite, requires a much smaller force to break it at the point of infection than is the case in normal branches of like age and thickness. The penetration and embedding of the vertical root system of the parasite in the wood of the host add nothing to the strength of the infected tissue, but diminish its normal strength when the force, as in the case of the wind, is applied at right angles to the grain of the infected branch. Since numerous infections occur at the bases of branches, the point of greatest stress, much injury to the tree results. The meristematic tissue in the cambium layer at the point

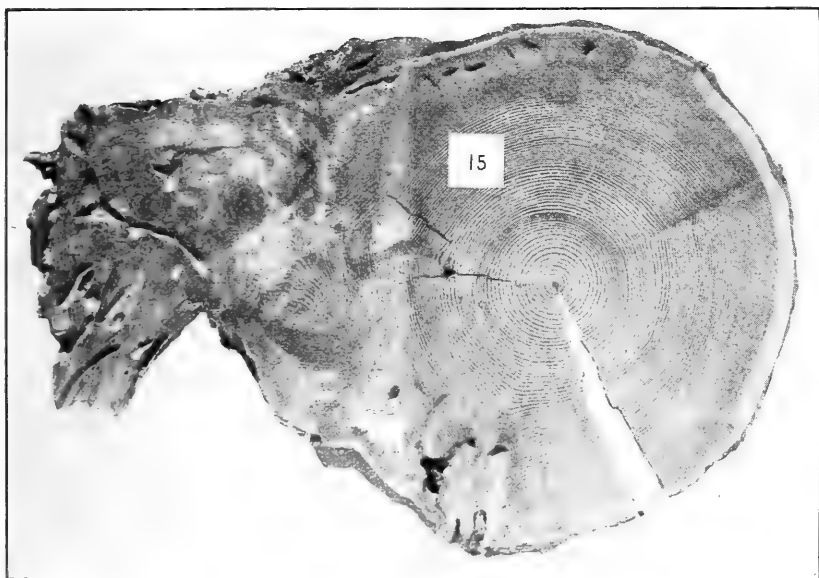


FIG. 5.—Cross section of the trunk of a larch tree, showing a typical basal branch burl. Note that the dead wood is attacked by borers which do not encroach upon the living sapwood.

where the branch breaks usually produces secondary branches (see fig. 2). These in turn may become infected and are lopped off, so that eventually great burls are produced at this point on the trunk (fig. 5), seriously reducing the merchantable material. The dead wood thus exposed is a place of entrance for insects and fungi. Since it requires years for the secondary branches to attain a size and assimilatory surface capable of supporting the present bulk of the trunk, the vigor of the tree is gradually reduced. The younger portion of the crown above, being continually encroached upon by the parasite, is not able to supply the deficiency in food materials, and the tree, merely existing for a time, finally becomes a prey to various

deteriorating agents and eventually dies before reaching its maximum development (fig. 6). The radial dimensions of the last annual ring of trees in the final stages of mistletoe suppression (fig. 7)



FIG. 6.—A larch tree in the last stages of mistletoe suppression. A few of the witches'-brooms contain living branches. The tree was making no perceptible increment and was far below the normal size for the region. It was necessary to clear away from the base of the tree the heap of fallen witches'-brooms before it could be cut.



FIG. 7.—Two larch trees barely living, as evidenced by dissection of the bole. Note the very large witches'-brooms and numerous dead branches.

were often so fine and narrow that they could be counted only with the aid of a compound microscope. In some of the worst cases the tree was able to produce but a single layer of tracheids in a year.

In so far as climate influences the prevalence and destructive effects of the larch mistletoe, that of the Blue Mountain region is most favorable. It might be here added that when a particular tree species has succeeded in establishing itself outside of what may be considered its optimum range and at the same time is followed up by a most destructive parasite which responds favorably to the habitat, the rapid deterioration of the species must necessarily follow, at least in the more unfavorable sites.

FUNGIOUS ENEMIES OF THE LARCH.

The larch on the tract examined was not attacked to any extent by fungi. The fungi collected were not present in sufficient quantity nor were their effects sufficiently evident to be considered the prime factor in the universal deterioration of the tree. The dead wood and bark of the mistletoe burls were usually infested by the larvæ of *Melanophila drummondi* Kirby (figs. 5 and 8) and occasionally were followed by a fungus causing a black stain. Two burls were found infected

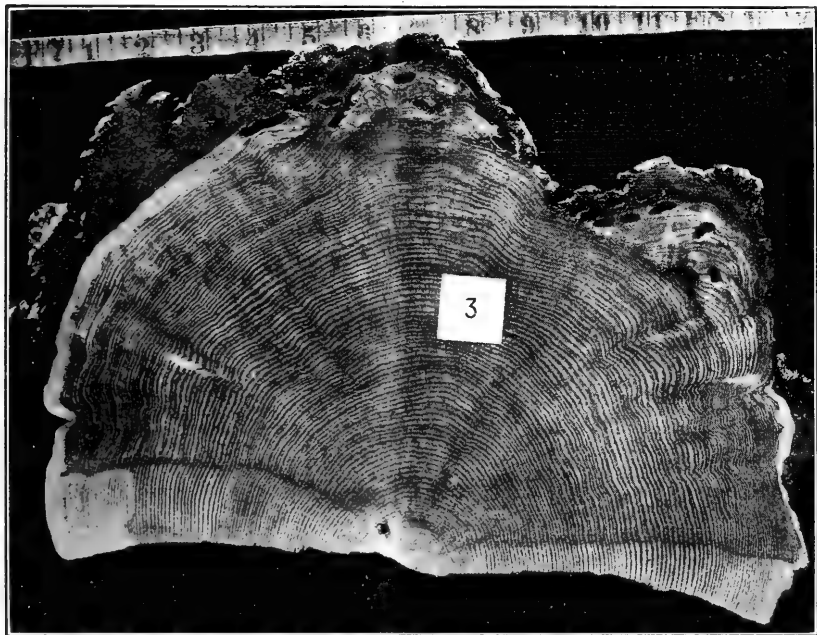


FIG. 8.—Cross section of the trunk of a larch tree, showing characteristic fan-shaped burl tissues resulting from an original infection when the tree was 7 years old. The tree was 145 years old when cut. Note the presence of borers. (Tape in feet graduated in twelfths.)

with *Trametes pini* (Brot.) Fr. (figs. 5 and 9), but here, as in a number of other cases where fungi had entered at the burl, the hardness and pitchy condition of the wood counteracted the advance of the fungus, and it had not spread much beyond the burl tissue. It is safe to state, from long field observations in other regions, that mistletoe burls furnish admirable starting points for fungi; but since the burl in its early stages is very pitchy (fig. 10) and the dead wood becomes pronounced only after the tree is greatly injured by the mistletoe itself, the effect of the fungi is to destroy later the merchantability of the tree, and the mistletoe may not be the original cause of its deterioration.

THE EFFECTS OF MISTLETOE ON ITS HOST.

A preliminary survey by the strip method made at the foot of a north slope and partly on the level resulted in the accumulation of the data given in Table I, showing conclusively that the larch in this region is heavily infected with mistletoe. No attempt was made to ascertain the age of the trees given here, so as to show the degree of suppression. A good idea may be obtained, however, of the nature of the infection, distribution, and quantity of mistletoe present on the trees. In general, the height of the trees here recorded is somewhat less than that of normal or uninfected trees in the same region.

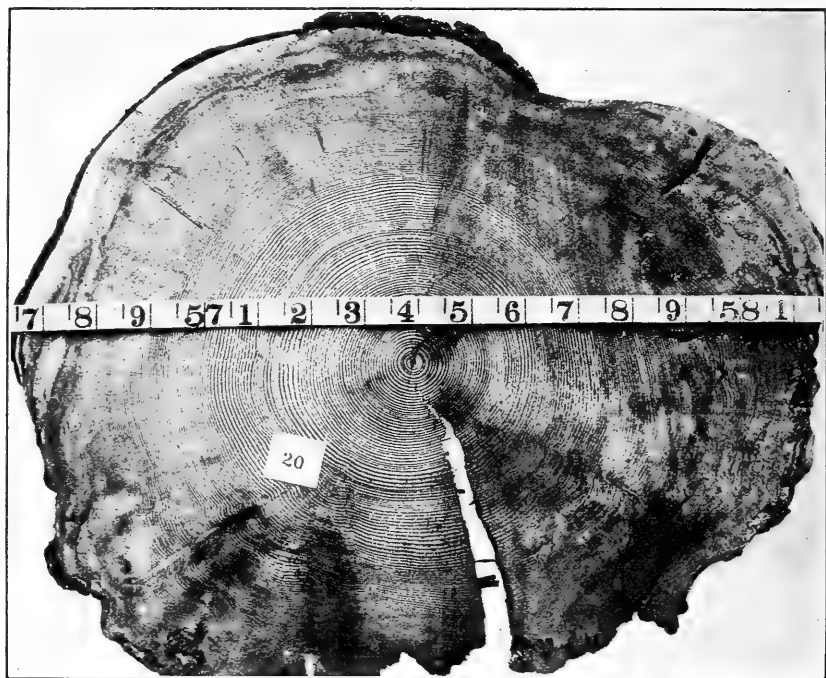


FIG. 9.—Cross section of the trunk of a larch tree, showing a large burl with white cellulose pits caused by *Trametes pini*. Note the small amount of living wood and that the dry wood is attacked by fungi and insects. (Tape in feet graduated in tenths.)

The youngest specimen found infected was less than 5 years old, which means, of course, that such early infection will not allow a very high state of merchantability to be attained, even if the young tree is not killed prematurely. Usually very young growth first becomes infected somewhere on the trunk where the bark is not yet protected by cork (fig. 11). The infection of very young seedlings causes them to assume various abnormal shapes and positions, especially when the mistletoe is confined to one side of the stem. Burl

tissues begin to form usually within a comparatively short time, from one to two years in young plants. If the infection occurs on the stem near the base of a branch, the cortical root system advances into the bast tissues of the branch, initiating a burl or witches'-broom at that point (fig. 1). The extension of the cortical roots upward along the main trunk is sometimes sufficiently rapid to keep within the 4 to 5 year old portion of the stem, although the larch mistletoe seldom

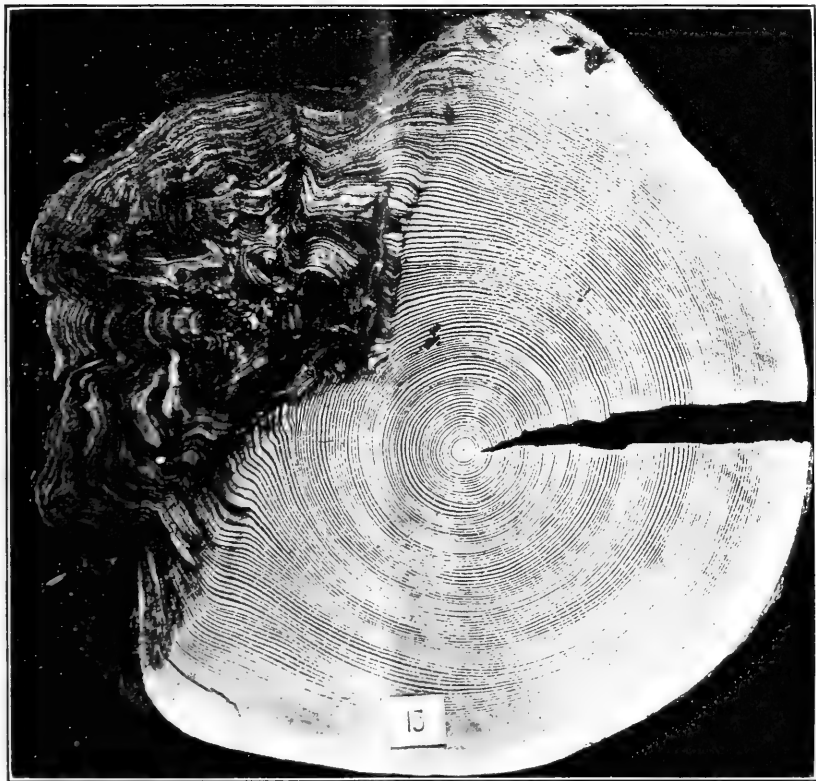


FIG. 10.—Cross section of a trunk of a larch tree with a large burl, showing its structure and a large pitch pocket.

spreads very far from the point of original infection. The parasite, however, usually travels more rapidly along the young shoots which develop in number at the place of first infection. The spread of the parasite outwardly along the branch or upwardly along the leader may be hastened by the dissemination of seeds from the older infections. In this manner the last year's growth is often infected, and even the terminal bud. The branches of the parasite eventually fall away, leaving scars easily discernible on the older parts of the young trees (fig. 1).

TABLE I.—*Extent and nature of mistletoe infection in 36 larch trees in the Whitman National Forest.*

Tree No.	Breast-high diameter.	Height of tree.	Number of burls.		Number of witches'-brooms.				General vigor of tree.	General merchantable condition.
			On trunk.	At base of branches.	At base of branches.	On branches.	Total on tree.	Fallen from tree.		
	<i>Inches.</i>	<i>Feet.</i>								
12.....	7	51	1	4	5	13	18	1	Poor..	.....
16.....	7	68	1	4	6	10	16	1	do..	Poor.
15.....	9	75	0	0	0	0	0	0	Good..	Good.
29.....	10	50	0	0	0	18	18	1	Fair..	Do.
11.....	11	85	0	2	2	12	14	1	do..	Do.
9.....	12	64	0	0	4	15	19	2	do..	Do.
10.....	12	66	0	0	3	16	19	0	do..	Do.
14.....	13	95	0	0	6	12	18	2	do..	Fair.
7.....	14	78	0	0	0	0	0	0	Good..	Good.
23.....	14	122	0	0	0	0	0	0	do..	Do.
5.....	15	98	1	0	4	8	12	2	Fair..	Fair.
13.....	15	84	0	3	4	15	19	3	do..	Do.
17.....	15	83	0	0	0	0	0	0	Good..	Good.
18.....	16	88	1	2	4	20	24	3	Poor..	Poor.
1.....	17	85	0	4	5	15	20	17	do..	Do.
21.....	17	88	2	8	4	20	24	3	do..	Do.
22.....	17	90	0	1	2	11	13	1	do..	Good.
19.....	18	99	1	0	3	8	11	1	Fair..	Do.
25.....	18	103	0	0	0	0	0	0	Good..	Do.
33.....	18	80	1	1	3	5	8	3	Fair..	Do.
2.....	19	99	0	0	0	0	0	0	Good..	Do.
23.....	20	103	1	2	4	18	21	4	Fair..	Fair.
24.....	20	120	0	3	3	20	23	6	do..	Do.
26.....	20	109	3	4	3	21	23	4	do..	Do.
8.....	22	107	1	1	3	10	13	0	do..	Good.
3.....	23	100	2	4	8	8	16	9	Poor..	Fair.
6.....	23	110	3	6	5	16	21	7	do..	Poor.
32.....	23	109	4	2	1	10	11	1	do..	Do.
30.....	24	110	1	2	3	15	18	4	Fair..	Fair.
36.....	25	111	2	3	4	10	14	4	Poor..	Poor.
27.....	28	126	0	0	0	0	0	0	Good..	Good.
28.....	28	110	1	2	1	10	11	2	Fair..	Do.
31.....	28	119	3	1	2	20	22	2	Poor..	Poor.
35.....	29	123	3	4	6	10	16	2	do..	Do.
4.....	29	125	0	14	5	20	25	6	do..	Do.
34.....	30	120	0	3	2	6	8	0	Fair..	Fair.

Owing to the slower growth of the branches in length as compared to the stem, the cortical roots of the mistletoe are enabled to extend into the older part of the 2-year-old internodes. After a time the branch is suppressed and the terminal bud becomes infected, resulting in a terminal broom. The cortical roots likewise penetrate the foliar spurs, causing them to become greatly enlarged, with the result that few leaves are produced (fig. 12). It is remarkable how rapidly in some instances the burl tissues become differentiated. A slight swelling is first noticeable; then the bark begins to lose its fresh appearance, becomes rough around the edges of the infected tissues, and finally separates altogether from the normal bark (fig. 11). The vertical roots of the parasite continue to live for many years, elongating with the same rapidity with which the annual increment of the host is laid down. The hypertrophied tissues resulting from these early infections on the stem spread out in fanlike shapes when viewed in cross section (figs. 8 and 10). Original infections on branches not only cause a local hypertrophy of the immediately

infected area (fig. 13), but large brooms are almost invariably produced.

In mistletoe regions no trees of any age are safe from infection. A great many trees surrounded by other species not attacked by the



FIG. 11.—The main stem of a young larch, showing two separate infections, one at the whorl of branches and the other on the internode. Both infections are of the same age, as indicated by the large primary sinkers, which terminate at the same annual ring. Note the rough bark on the swellings, the beginning of typical trunk burls. The branches of the mistletoe have fallen, but the sinkers are still living and will remain alive for an indefinite period, stimulating the host tissues to a greater development. The central areas of the burl soon die, leaving an open wound.

same mistletoe escape early infection and grow to a fair size, with normal, healthy crowns. Such uninfected trees are always conspicuous among their more heavily infected neighbors. These trees are eventually attacked, but owing to the advantage of a somewhat isolated position, they may not become badly infected, since the seeds must be brought from a distance greater than the natural expelling force of the seed capsule is capable of exerting. Undoubtedly this force is aided by the wind.



FIG. 12.—A larch twig, showing the abnormal size of the folliar spurs when stimulated by the parasite. These spurs are nearly four times the size of the normal spurs on the same branch.

The final result is the infection of the terminal twigs, and in most cases those of the lower branches. The infection gradually spreads upward; the branches either become broomed

and are broken off, followed in many cases by a secondary crown (figs. 3, 4, 6, and 7), too late to supply the deficiency in food materials; or the vigor of the present bulk growth and the vitality of the tree are reduced by a general infection throughout the entire crown. The latter type of mistletoe injury frequently occurs. The tree seems to become infected at many different parts of the crown at once, and while the branches are not broken by the formation of large brooms, the vitality of the host gradually sinks under the drain on its resources of so widespread an infection. When young trees are infected there is such an excessive broom development by the time they have reached pole size that the original crown has practically

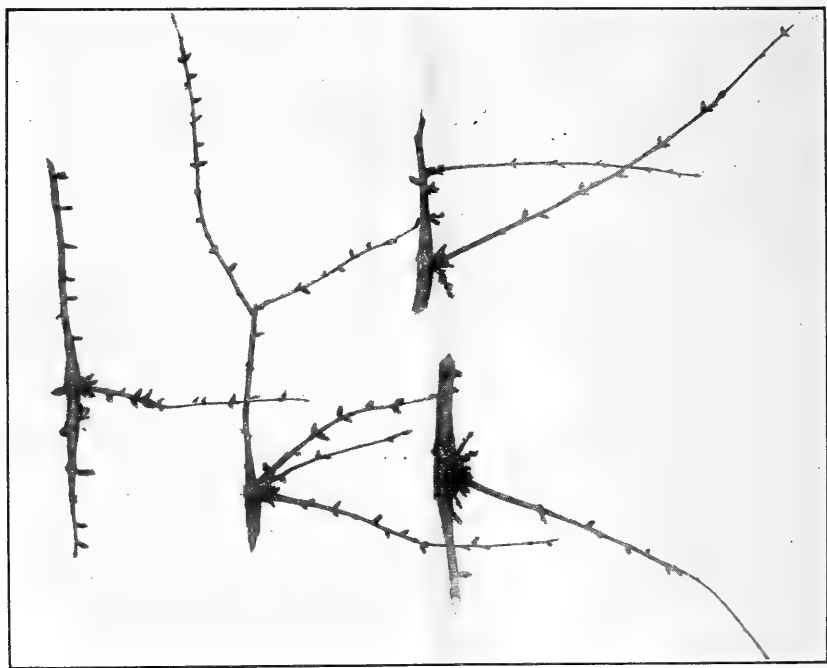


FIG. 13.—A common type of original infection on a larch branch, showing the beginning of branch witches'-brooms.

disappeared. Bushy secondary branches grow out from the stumps of the old ones, and the lopping process may be continued to a third or fourth generation of branches (fig. 2). The width of the secondary crowns becomes less and less, until practically nothing remains but the stubs of the former branches, bearing a few straggling green twigs (figs. 3, 6, and 7). By this means the assimilatory surface of the tree is gradually reduced. During the period between the fall of the primary and the appearance of the secondary branches, the tree is robbed of a great amount of food material necessary to maintain its vigor at its present stage, and it begins to show signs of

developing a "spike top" (figs. 4, 6, and 7). All heavily infected trees by the time they have reached the age of 200 years, if they succeed in living to that age, have developed a "spike top" (Table II).

Occasionally infected trees attain a considerable size, due to the fact that the original infections occurred chiefly at the bases of the branches and did not spread. The attendant broom formation occurring on the branches next to the trunk allows the retention of the branches for a longer time than if brooms were developed farther out on the branch. The merchantability of the tree is greatly reduced, however, by the formation of a series of basal branch burls, causing streaks of pitchy wood to extend along the trunk from one burl to another.

The spread of the parasite in the direction of the prevailing winds was very interestingly shown in a number of cases. One case in particular was noted in which a series of trees of nearly the same age standing in a row extending in the general direction of the more constant winds indicated that the infection had gradually traveled from the first and most seriously infected specimen to those least infected at the other end of the row. These trees had apparently originated under the protection of an old windfall. Since there were no infected trees immediately to the right or left, it is fairly evident that the wind was a factor in seed distribution and also determined the direction of distribution. In order to appreciate thoroughly the significance of the effects of mistletoe on the larch, a study should be made of figures 3, 4, 6, and 7, representing different stages of suppression and various types of infection.

On the drier slopes, from 80 to 90 per cent of the larch of all ages has been found infected. On the more favorable sites, the percentage of infection was very low and therefore did not interfere seriously with the best development of the species. (See trees Nos. 40 and 41, Table II.)

After the preliminary survey, and in order to answer definitely the question whether or not mistletoe is as great an enemy to the host as outward appearance seems to indicate and to obtain, as near as possible, comparable figures on mistletoe injury, 45 infected and uninfected trees were cut and such measurements taken as were thought necessary for the needs of the problem in hand. These data, along with many other observations having a bearing on the subject, have been arranged in Table II, whereby it is possible to follow out the main factors operative in the deterioration or suppression of the trees studied and by means of which fairly conclusive comparisons may be drawn.

TABLE II.—Comparison of 45 larch trees in the Whitman National Forest with respect to mistletoe infection.

[Abbreviations: In columns 14 and 40, increasing degree of infection is shown by the number of cross marks; in columns 26, 31, and 32, B=borers, F=fungi, S=sound, St=stain; in column 36, D=dominant, I=intermediate, S=suppressed.]

Age of tree.	Tree No.	Branch burls.		Branches on burls.		Highest point of infection.	Branch witches'-brooms.	Length of spike top.	Average weight of—		Average diameter of branch.	
		Number.	Average height.	Living.	Originally.				Normal branches.	Branch witches'-brooms.	Supporting witches'-brooms.	Normal, same part of whorl.
1	2	3	4	5	6	7	8	9	10	11	12	13
Yrs.			Feet.			Feet.		Feet.	Pounds.	Pounds.	Inches.	Inches.
30	45											
63	27											
63	42					47.0	7		2.0	3.0	0.5	0.8
74	26											
90	6					Tip.						
94	1											
96	9											
96	43	2	20.0	8	10	57.0	6		3.0	4.5	1.0	1.5
100	7	3	35.3	10	18	80.0	6			4.5	1.3	
105	8	1	23.0	3	4	77.0	5		5.25	3.2	1.3	1.5
106	10	1	23.0	2	2	59.0	24		1.6	3.2	1.0	.75
107	11											
111	4											
119	14											
122	25	8	22.4	23	38	55.5	9			3.8	1.0	
123	5	2	38.0	10	14	82.0	18		2.0	3.0	1.0	.75
123	44											
128	13	3	25.3	15	7	88.5	38		3.2	6.0	1.75	1.50
136	12					108.0	17			8.0	1.0	
143	22											
145	3	5	56.4	15	21	92.0	13		4.5	8.0	1.0	1.75
145	39											
147	19											
180	23	12	41.9	37	72	101.0	10		6.0	8.5	1.0	2.10
183	31	6	49.1	6	20	109.0	6		6.0	10.0	1.0	2.0
205	15	12	35.9	14	40	Tip.	(a)			(a)		
216	16											
222	17	5	37.4	9	21	110.0	11		5.0	8.0	.95	1.8
224	36	5	39.2	10	31	Tip.	1	16				
225	29	4	47.0	3	25	Tip.	(a)		(b)		(b)	
226	35	12	49.0	5	58	Tip.	1		(c)			
227	33	9	71.2	23	51	Tip.	10	10				
229	28	11	45.5	17	53	Tip.	10	12	(d)		(d)	
233	34	5	53.0	3	28	Tip.	(a)		(d)		(d)	
235	18	6	48.3	7	33	Tip.			(e)	(e)		
245	30	5	54.4	4	19				(f)			
245	37	4	43.0	3	21	93.0	2		(g)			
248	32	7	42.0	7	29	Tip.	1			25.0		
249	2	12	37.5	19	85	Tip.		7	(h)			
249	12	10	49.3	5	46			24	(i)			
252	38	6	67.4	10	39	Tip.			(j)			
253	20	3	34.6	2	18	Tip.		42	(k)			
271	24											
566	40											
623	41											

a Branch witches'-brooms fallen to ground.

b Most original branches broken off.

c One original branch.

d Original branches broken off.

e Crown secondary.

f Branches fallen; last stage.

g Crown secondary, infected.

h Branches all fallen.

i Upper crown heavily infected.

j Branches secondary.

k Branches mostly fallen.

TABLE II.—Comparison of 45 larch trees in the Whitman National Forest with respect to mistletoe infection—Continued.

Age of tree.	Tree No.	Rings comprising present period of suppression.			Condition of heartwood.	Height (feet).		Full volume, b. m.	Dominance.	Diameter, breast high.	Height of stump.	Growth for last 10 years at stump.	Degree of infection.
		Width.	Number.	Condition.		Total.	Merchantable.						
1	2	29	30	31	32	33	34	35	36	37	38	39	40
Yrs.		Inches.						Feet.		In.	Feet.	In.	
30	45	0.25	15	S	S	7	-----	0	S	0.75	-----	-----	xxx
63	27	0	0	S	S	60	-----	40	I	6.65	1.0	0.60	0
63	42	.5	20	S	S	53	-----	25	D	5	1.0	2.80	a xx
74	26	0	0	S	S	52	-----	20	I	6	1.0	.70	0
90	6	.4	30	B	B	51	-----	20	S	6	1.0	.10	xxx
94	1	0	0	S	S	77	58	340	D	15	1.2	1.20	0
96	9	0	0	S	S	72	32	80	I	9	1.0	1.00	0
96	43	.4	30	S	S	65	30	20	D	6	1.0	.10	xxx
100	7	.2	6	S	S	93	48	165	D	11	1.3	.80	xxx
105	8	.3	4	S	S	95	64	265	D	14	1.2	1.00	xx
106	10	.4	30	S	S	67	0	40	I	7	1.0	.40	xxx
107	11	0	0	S	S	93	64	325	D	16	1.0	2.00	0
111	4	.4	14	S	S	85	48	140	I	11	1.3	.60	xx
119	14	0	0	S	S	122	80	665	D	14	1.5	2.00	0
122	25	0	0	S	S	64.5	16	75	D	9	1.5	.70	xxx
123	5	.3	20	S	S	84	48	170	D	11.5	1.3	.10	xx
123	44	0	0	S	S	95	50	0	D	20	-----	-----	0
128	13	.25	10	S	S	93.5	64	435	D	17	1.5	.50	xx
136	21	.2	10	S	S	114	66	485	D	19.5	1.5	.40	xx
143	22	0	0	S	S	113.5	82	595	D	18	1.5	.80	0
145	3	.2	30	S	S	95	64	240	D	13	1.5	.30	xxx
145	39	0	0	S	S	123	94	1,045	D	22	1.6	1.30	0
147	19	0	0	S	S	102	80	550	D	17	1.5	1.20	0
180	23	2.5	30	S	S	113	82	920	D	21.5	1.5	.10	xxx
183	31	.15	10	S	S	119	82	1,010	D	24	1.5	.30	xxx
205	15	1.2	86	S	S	100	64	430	D	17	1.5	.20	xxxx
216	16	1.2	10	S	S	131	92	720	D	18	1.0	.40	x
222	17	.25	25	S	S	119	80	885	D	21	1.5	.70	xxx
224	36	.15	20	S	S	86	50	160	I	11	1.5	.10	xxxx
225	29	.5	40	S	S	106	82	590	D	19	1.5	.20	xxxx
226	35	.45	35	S	S	121	82	790	D	20	1.5	.20	xxxx
227	33	.4	38	S	S	131	98	1,540	D	26	1.8	.10	xx
229	28	.25	36	S	S	107.5	82	700	D	18	1.0	.10	xxxx
233	34	.15	14	S	S	104.5	65	380	D	16	1.5	-----	xxxx
235	18	1.5	73	S	S	121	80	820	D	20	1.0	.20	xx
245	30	.75	48	S	S	113.5	82	675	D	19	1.3	.20	xxxx
245	37	1.15	6	S	S	97	60	380	I	14	1.5	.60	xxx
248	32	.25	20	S	S	84.5	50	305	S	14	1.5	.10	xxx
249	2	2.5	80	S	S	112	90	905	D	21	1.4	.20	xxx
249	12	1.9	95	S	S	88	48	470	D	18	1.0	.06	xxxx
252	38	.25	20	S	S	120.5	82	780	D	21	1.5	.20	xxx
253	20	.6	50	S	S	112	81	870	D	21	1.4	.20	xxxx
271	24	0	0	S	S	133.5	98	1,905	D	31	1.5	.40	0
566	40	-----	-----	-----	S	160	-----	-----	-----	43	2.0	.40	0
623	41	-----	-----	-----	S	165	-----	-----	-----	51	2.0	.50	0

a The section passed through burl tissues.

The trees were selected from a comparatively small area after the preliminary survey had shown the nature of the deterioration to be universal and similar over large areas of the same type of stand. Although the numerical basis for the figures in the table is very meager, interesting results are shown, which fully justify the arrangement. In the absence of suitable volume-table studies of the normal growth of the same age class for the region, the arrangement of the table is based entirely on the trees felled for study. An increasing degree of infection is indicated by the larger number of cross marks employed (columns 14 and 40). Selecting trees of the same age, the study of the table may proceed as follows: Trees Nos. 42 and 27 are of the same age. The infection of No. 42 is xx; of No. 27, 0. By consulting column 27 the average width of sapwood for tree No. 42 is found to be 0.53 inch, and column 28 shows that the sapwood consists of an average of 16 rings; tree No. 27 has an average width of sapwood of 0.9 inch, with an average of 21.3 rings. Tree No. 42 showed a present period of suppression of 20 rings (column 30), the combined width of which is 0.5 inch (column 29); tree No. 27 has no present suppression and is marked 0 in the table. The condition of the sapwood, sound for both trees (column 31), indicates the absence of secondary causes of deterioration, as does in like manner the column (32) on the condition of the heartwood. Referring to other columns, tree No. 42 is shown to have a total height of 53 feet (column 33), a full volume of 25 feet, board measure (column 35), a breast-high diameter of 5 inches (column 37), and is dominant (column 36); tree No. 27, on the other hand, has a total height of 60 feet, a full volume of 40 feet, board measure, a breast-high diameter of 6.65 inches, and is sufficiently overtopped and crowned by its neighbors to be marked intermediate.

The fact that the infected tree stood fairly in the open, with no deteriorating agents other than mistletoe associated with it, leaves small room for doubt that the tree was suppressed by the parasite upon it. Table II shows that tree No. 42 has seven branch brooms (column 8), with an average weight of 3 pounds per broom (column 11) on and above the average weight of the normal branch, which is 2 pounds (column 10).

The effects of the mistletoe on its host are further shown by the differences in the diameters of branches supporting brooms and those not so encumbered (columns 12 and 13). The analysis of these trees showed that both individuals started equally, but the measurements and study of all cross sections showed plainly a retarded growth during the last few years of life except at the stump, the section passing through burl tissues (column 40). The age of the tree can not be held responsible for the falling off in increment. A comparison of the measurements taken at the various cross sections and at

the stump was found to vary so little that the stump measurements were adopted to show the falling off in growth for the last 10 years. A study of all the cross sections of tree No. 27 showed a normal growth. It also possesses a crown of larger dimensions. The two trees stood within 100 feet of each other. Selecting from Table II that which is of greatest moment, trees Nos. 43 and 9 may be compared as shown in Table III.

TABLE III.—*Condition of larches Nos. 43 and 9, selected from Table II for comparison.*

Item of comparison.	Tree No. 43.	Tree No. 9.
Age.....years.....	96	96
Breast-high diameter.....inches.....	6	9
Infection.....	xxx	0
Average width of sapwood.....inches.....	1.12	1.35
Average number of rings in sapwood.....	23	27
Width of present zone of suppression.....	(inches.. 0.4	0
	(rings.. 30	0
Height.....feet.....	65	72
Merchantable length.....do.....	20	32
Full volume, board measure.....do.....	20	83
Growth for last 10 years.....inches.....	0.10	1
Relation to neighboring trees.....	Dominant.	Intermediate.

Tree No. 43, as shown by the data in Table II, had burls on its trunk and at the bases of branches (columns 3 and 15). A trunk burl occupied 100 per cent of its total circumference (column 20) and only 10 per cent of it was living (column 23). The tree had six branch brooms (column 6), with an average weight of 4.5 pounds (column 11), and normal branches of 3 pounds average weight (column 10).

In this manner tree No. 5 may be compared with tree No. 44; No. 10 with No. 11; No. 3 with No. 39; No. 5 with No. 25; No. 33 with No. 35; No. 2 with No. 12; No. 30 with No. 37; No. 33 with Nos. 35, 29, or 36; No. 18 with No. 34, etc.

EFFECT OF MISTLETOE BURLS ON THE MERCHANTABILITY OF LARCH TREES.

The effect of the formation of burls on the trunk and at the bases of branches, aside from injuring the tree from a physiological standpoint by cutting off the transporting tissues, introduces a cull factor of no mean proportion in the present timber capital. In bucking the tree it is possible in most cases to saw out the burls when they are far enough apart not to interfere seriously with the merchantable log length. In badly infected specimens the trunk and branch burls (figs. 5, 8, 9, and 10) are frequently so close together and so evenly distributed along the trunk that little merchantable material can be obtained. Sometimes these burls take up the entire merchantable

part of the tree and are very frequently more than 10 feet in length. Streaks of discolored wood, usually pitchy, and long checks may often extend from burl to burl, producing a very poor grade of lumber. Table IV shows the quantity of culls resulting from the mistletoe burls.

TABLE IV.—*Culled larch lumber resulting from mistletoe burls.*

Age of tree.	Tree No.	Trunk burls.						Basal branch burls.			
		Burl No.	Average diam-eter.		Length.	Volume, b. m., of culls due to burls.		Maxi-mum diam-eter. ^a	Num-ber.	Volume, b. m., of culls due to burls.	
			At base.	At top.		Each.	For tree.			Each.	For tree.
Years.			Inches.	Inches.	Feet.	Feet.	Feet.	Inches.		Feet.	Feet.
90	6	{ 1	6.6	6.1				7.0			
96	43	{ 2	3.5	3			(b)	3.5		(b)	165.0
		{ 1								(b)	20
100	7	{ 2	12.3	12	1.5	12		12.3	3	1.4	
		{ 2	11.5	11	1.2	9.3	26.8	11.5			28.2
		{ 3	10.1	10	1	5.5		10.1		1.4	
105	8	{ 1	15.1	14.8	3	25	25	15.1	1	2.5	27.5
106	10	{ 1	8.1	7	9	14.5	14.5	9	1	1.4	15.9
122	25	{ 1	13.5	12.7	3	20	20	13.5	8	20	40
123	5	{ 1	8.6	8.3	2	8	8	16	2	5	13
128	13								3	10	10
		{ 1	12	11.8	2.3	15		12	5	30	
145	3 ^c	{ 2	11.6	11.5	2	10		11.6			67.5
		{ 3	11.4	11.3	2	6.5	37.5	11.4			
		{ 4	10.8	10.6	2	6		10.8		30	
180	23								12	180	180
183	31	{ 1	23.2	23	3	70		23.2	6	175	245
205	15	{ 1	13.1	13	3.5	25	(d)	15.5	12	170	195
216	16	{ 1	18.5	18	4	67.5		18.5			67.5
222	17	{ 1	18.1	17.9	16	190		20	5	80	
		{ 2	17.7	17.5	2	22	212	18		80	292
224	36								5	30	30
225	29	{ 1	13.1	13	2.5	20		13.5	4	20	40
226	35	{ 1	12.8	12.3	4	25		12.8	12	140	165
227	33								9	190	190
229	28	{ 1	18	17.8	7	110		18	11	150	260
233	34								5	60	60
235	18								6	80	80
245	30								5	70	70
245	37								4	60	60
248	32	{ 1	10.9		16	70		12	7	75	145
249	2								21	190	190
249	12								10	110	110
252	38								6	95	95
253	20	{ 1	18	17.8	16	210	(e)	19	3	120	330

^a Average diameter taken between middle line of burl and either extremity.

^b Tree culled.

^c See figure 8.

^d See figure 10.

^e See figure 9.

METHOD OF CONTROL.

Since mistletoe is propagated and spreads from tree to tree by means of seeds, the method to be employed in eradicating it is similar to that which is now being adopted in many sales areas for reducing the ravages of forest-tree fungi. Results will be obtained in a much shorter time, however, than in the case of fungous enemies. Mistletoe occupies only the aerial part of the host. Fungi attack all parts—roots, stems, and leaves; hence, cutting an infected tree does not

eliminate some of the worst fungous enemies of the forest. Those of the roots escape and others attacking the aerial portion of the tree afterwards in many cases develop quite as vigorously on the dead wood as before. On the other hand, the mistletoe plant dies with the death of the host. Although the seeds of the mistletoe are expelled from the pericarp with considerable force, they are not carried, even though aided by wind, for great distances, as are the spores of fungi. Birds and rodents¹ are factors in the distribution of mistletoe seeds, but the actual service rendered the parasite by such agencies is very small. It is very evident, then, that no trees, young or old, infected with mistletoe should ever be selected for seed trees, because all young growth beneath such trees and in the near vicinity would be in great danger of infection. By a gradual process of elimination on every timber-sale area, governed by a clause in the contract requiring the taking down or girdling by fire of every mistletoe-infected tree, much may be accomplished within a comparatively short time.

CONCLUSIONS.

The principal conclusions which may be drawn from the present study are summarized as follows:

The deterioration of the western larch in the more open and exposed stands of the Whitman National Forest is due to mistletoe. Although yellow pine and Douglas fir are the most valuable species, the larch, when free from mistletoe, attains a size on any site, so far as observed, sufficient to merit its being carried along in the rotation with the other species. From the fact that the larch mistletoe finds its optimum development in the more exposed sites, future silvical operations should aim at confining the larch to moist bottoms and protected valleys.

Since the principal defects of the western larch, excluding pitchy butt and shake, originate from mistletoe, the diameter and age limit of this tree may be greatly extended, provided methods for the eradication of the mistletoe are adopted.

The larch mistletoe attacks trees of all ages, from seedlings to the unsuberized parts of mature trees. If not entirely suppressed or killed, trees attacked in early life seldom produce a good grade of merchantable timber. All trees seriously infected show poor health and reduced diameter or height. Trees becoming infected in middle life may have the quality of the timber reduced by the large knots formed by the basal branch burls.

¹ The common English sparrow has been observed by the writer to feed upon the seeds of the yellow-pine mistletoe in the city park at Coeur d'Alene, Idaho. Mistletoe seeds have been found in the excrement of birds in mistletoe regions. Birds and rodents frequently build their nests in mistletoe brooms and are known by actual investigation to play a minor rôle in the distribution of the seeds of the parasite.

Burls found in early life on the trunk cause suppression by reducing the food-transporting tissues, form open wounds for the entrance of fungi and insects, and cause streaks of pitch to appear in the wood, which often extend from one burl to another. Burls formed at the bases of branches produce similar injuries and may also cause a premature pruning of the branch.

The extra weight of the brooms, together with the accumulated debris, causes the branches to break off readily under the influence of the wind and deprives the tree of its normal food supply.

Mistletoe thrives best on trees of uneven stands. In dense, close, even-aged stands, as in deep valleys, the parasite usually causes less damage.

The type of infection working the greatest injury in the shortest time is the formation of brooms on the branches.

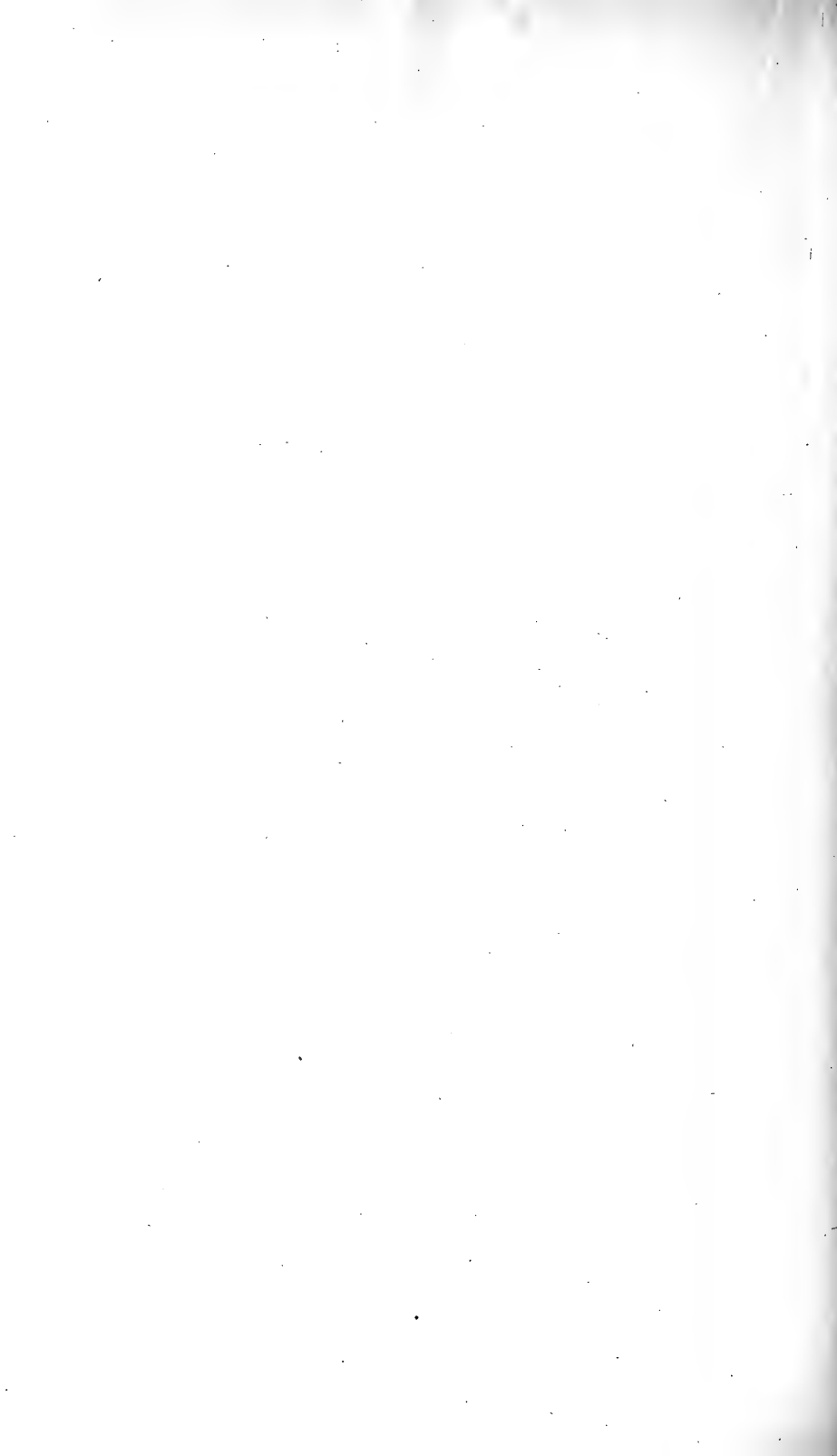
Thinning promotes the development of the parasite in the crown; hence, all infected trees of any size, age, and condition should be marked for cutting.

The mistletoe spreads more rapidly in the crowns of younger trees, owing to the greater number of twigs in close proximity susceptible to infection.

Two types of infection by the mistletoe occur: (1) By the seed falling on the branches, where a broom usually develops if infection occurs, and (2) the gradual advance of the cortical root system of the mistletoe along the branch to younger tissues. The seeds of mistletoe have been known to fall on the healing tissue of wounds on old parts of trees, causing infection.

Suppression by mistletoe causes a more rapid and an earlier formation of heartwood in the younger age classes, thus inviting insects and fungi at earlier periods of growth.

Mistletoe may be controlled by inserting in all timber-sale contracts a clause requiring the cutting on the sales area of all larches infected with mistletoe, whether merchantable or unmerchantable.



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THE BONAVIST, LABLAB, OR HYACINTH BEAN.

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INTRODUCTION.

The bonavist is a native of India and has been cultivated since ancient times. In tropical and subtropical countries it is generally grown for human food, the young pods of some varieties being used after the manner of string beans. In India, China, and, formerly at least, the West Indies, the dried seeds of certain varieties are also used as food. In temperate countries it is more commonly known as an ornamental plant, especially the purple-leaved floriferous varieties, which are often used to grow over trellises or porches. To some extent the bonavist has also been used for forage and as a green-manure crop. Judging from the reports of early writers its use for such purposes in the Southern States was formerly common, but the plant is now rarely used there as a field crop.

CULTURAL CHARACTERISTICS.

In most respects the bonavist is closely comparable to the cowpea, but it is more vigorous and more viny. A single plant of some of the sorts will produce under favorable conditions at least twice as much herbage as a single plant of any cowpea. The stems are tougher and more fibrous and the leaves less succulent. Like the cowpea, the bonavist is indeterminate in growth, blooming and fruit-

ing as long as the conditions remain favorable. The best bushy or half-bushy sorts planted in 3-foot rows make much the same type of growth as the cowpea, and under the same conditions will produce a greater yield of hay, which is more easily cured, owing to its smaller moisture content. The plants are markedly drought resistant, and under the conditions existing at Chillicothe, Tex., suffer less from drought than cowpeas.

The bonavist is also well adapted to planting with corn or some other supporting crop. In corn the vining habit of the plant becomes accentuated, and some of the more vigorous varieties will grow across the rows, making a tangled mass difficult to handle when cutting for silage. On the whole, however, the bonavist is closely comparable to the cowpea in value for planting in corn.

SEED PRODUCTION.

The principal weakness of the bonavist, considered as a forage crop, is the relatively poor yield of seed and the difficulty of harvesting the same, which makes it expensive. From a seed-production standpoint the most desirable varieties are those in which the pod retains its form when dry, as these are not much affected by wet weather and thrash out rather easily.

VARIETAL CHARACTERS.

The bonavist varies in all its parts perhaps more than any other legume, which fact accounts in part for its numerous botanical names. This variation is, moreover, far greater than botanical diagnoses have indicated, so that several varieties answer equally well to some of the brief descriptions. The characters that distinguish varieties in the bonavist may be briefly discussed as follows:

Habit.—Most varieties are very viny, but a few strictly bush sorts occur. The most vigorous kinds will climb on trellises to a height of 20 to 30 feet.

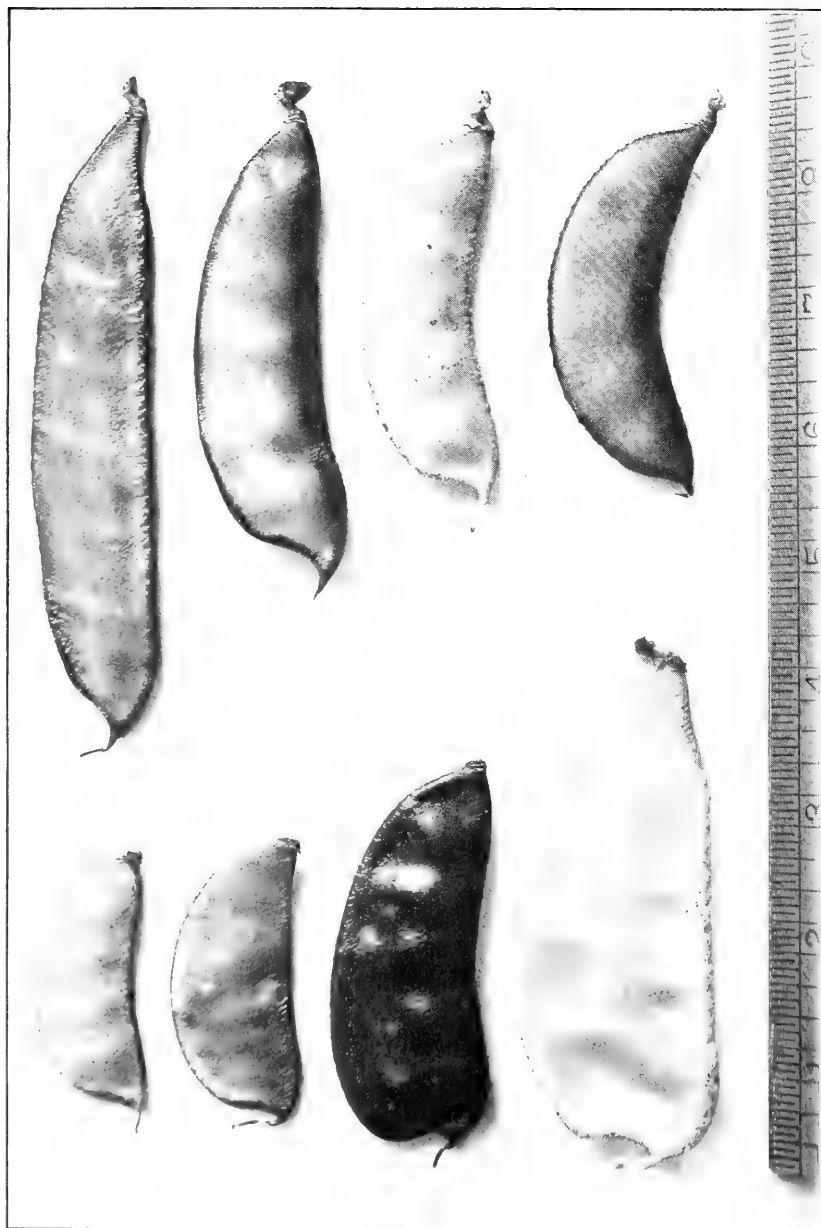
Life period.—At Arlington Farm the earliest varieties ripen their first pods in about 100 days. Many kinds are not even in bloom when killed by frost after about 140 days. The wild plant is said by most writers to be perennial, but the cultivated sorts are annuals. A variety commonly cultivated in the Philippines as a vegetable endures there at least two years, and this is probably a common occurrence with the plant in the Tropics.

Color of herbage.—In some varieties every part of the plant is more or less deeply purple tinged, while in others there is no trace of this color. In a few sorts only the stems, petioles, and principal leaf veins are purple.

Pubescence.—Many varieties are covered with short, white hairs, so that the foliage is pale and dull. Other sorts are bright green and nearly glabrous.

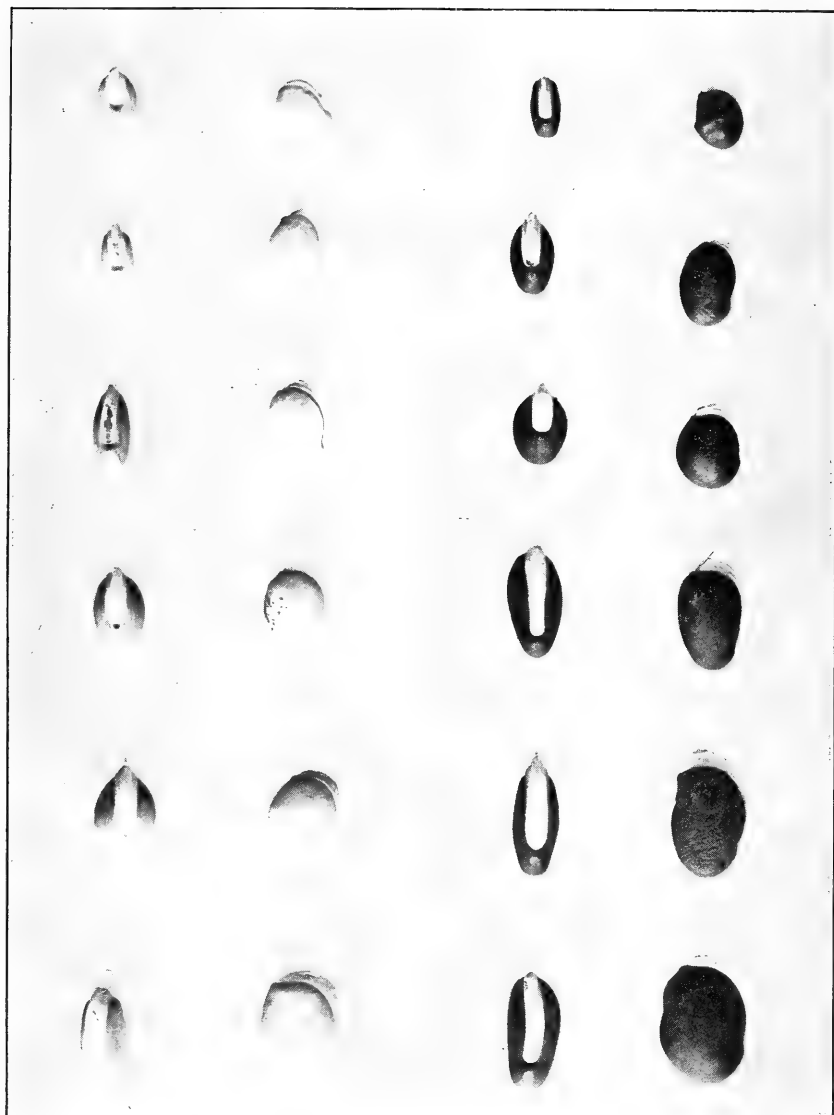
Leaflets.—The leaflets vary considerably in size and color and to a slight degree in shape.

Flowers.—Two colors occur in the flowers, white and pink purple. There are also differences in the size of the corolla and the degree of fragrance. More striking are the differences in the length of the peduncle, the abundance of



FULL-GROWN BUT NOT MATURE PODS OF EIGHT VARIETIES OF BONAVIST.

These beans are listed in the inventories of the Office of Foreign Seed and Plant Introduction as Nos. 8356, 25132, 21998, 17534, 26358, 8686, 27533, and 31363, reading from left to right.



SEEDS OF TWELVE VARIETIES OF BONAIVIST, SHOWING THEIR RANGE IN SIZE AND SHAPE.

These beans are listed in the inventories of the Office of Foreign Seed and Plant Introduction as Nos. 25158, 4380, 25157, 27532, 8686, 25132, 21998, 25154, 25915, 8355, 21352, and 25727, reading from left to right.

the flowers, and the size of the panicles. In many sorts the panicles are short peduncled and 10 to 20 flowered, while in the more floriferous kinds the long-stalked panicles are a foot in length and 20 to 30 flowered.

Pods.—The pods vary greatly in size and shape (Pl. I). The color may be green, white, purple, or purple margined. In some of the green-podded sorts the pods are fibrous and retain their shape when fully ripe, but most of the cultivated varieties have more or less fleshy pods, which shrink and become distorted at maturity. The fleshy-podded sorts are the best for use as snap beans.

Seeds.—The seeds vary greatly in size, shape, and color (Pl. II), and furnish along with the pods the easiest characters by which to identify varieties.

Susceptibility to disease.—All of the varieties of the bonavist are remarkably free from leaf diseases. Many, if not all, however, are subject to both *Fusarium* root-rot and to nematodes.

VALUE FOR HUMAN FOOD.

The green pods of some varieties of the bonavist are much used in the Tropics as snap beans; indeed, they have been called by Roxburgh "the kidney beans of the Asiatics." Other varieties are not thus eaten in India, being called bitter. One variety has for some years been sold by Vilmorin under the name "Stringless" (S. P. I. No. 20447). This produces an abundance of large, fleshy white pods, which, cooked after the manner of string beans, are very good. This variety should be generally grown from Maryland and Kentucky southward, as it not only produces an abundance of edible pods, but incidentally makes an attractive arbor vine.

The use of the dry seeds for food is less common, but some varieties are thus utilized in India and China.

Under some conditions prussic acid is formed in the seeds. Thus Leather (8)¹ found that the poisonous acid was formed when the crushed seeds of the bonavist were allowed to remain in cold water a few hours.

Mr. O. F. Black, chemical biologist of the Office of Drug-Plant, Poisonous-Plant, Physiological, and Fermentation Investigations, who upon request examined seeds of S. P. I. Nos. 8356 (blackish), 22025 (dark purple), and 25156 (cream color), all grown at Arlington Farm in 1913, to see if hydrocyanic acid could be detected, made the following report:

The dry seeds were ground, suspended in dilute sulphuric acid, and distilled with steam. The distillate was tested for hydrocyanic acid, with negative results in every case.

Nos. 8356 and 22025 were germinated in the greenhouse in sphagnum moss until the roots were 3 to 4 centimeters long and then tested in a similar way, but gave no evidence of the presence of hydrocyanic acid.

¹ The numbers in parentheses refer to "Literature cited," page 15.

BOTANICAL NAMES.

Dolichos lablab is the usual botanical name applied to the bonavist, and apparently this species must be considered the type of the genus *Dolichos*. By some botanists the bonavist is not considered congeneric with most of the species that have been included in the genus *Dolichos*. On this account Adanson established the genus *Lablab* in 1763 (1), which has been accepted by many botanists. Whether one genus be recognized or two, the name *Dolichos* should be maintained for the bonavist, as this clearly stands for Linnæus's idea of the genus.

Dolichos lablab was so named in 1753 by Linnæus (10), who based it primarily on an Egyptian plant described and figured by Alpino (2). *Lablab*, or *liblab*, is the Egyptian name. Alpino describes the seeds as black or dark reddish, but does not state the color of the flowers. Later writers seem to have overlooked the fact that the species is based on Alpino's Egyptian plant. De Candolle (3, p. 401) calls the black-seeded Egyptian plant *Lablab vulgaris niger*. Schweinfurth and Muschler (13) name a purple-flowered Egyptian variety *Dolichos lablab* var. *hortensis*, but this is not unlikely the same as that originally described by Alpino.

Linnæus (11, p. 1021) later described as a species *Dolichos purpureus*, based on a plant from the Indies with flowers, stems, petioles, and leaf veins purple. This name as used by later botanists has usually been considered a variety of *Dolichos lablab* and has been applied to any sort that had the foliage more or less purple tinged.

Dolichos benghalensis Jacquin (6) represents a variety of bonavist from Bengal with white flowers, white, fleshy, falcate pods, and reddish purple seeds. It is very similar to S. P. I. No. 25154. De Candolle (3, p. 401) renamed Jacquin's plant *Lablab vulgaris* var. *albiflorus*.

Dolichos albus Loureiro (12), from Cochin China and China, is based on a sort with white flowers and pubescent leaves, but the color of the seeds is not stated.

Lablab perennans De Candolle (3, p. 402) is based on Loureiro's (12) description of *Dolichos albus*. De Candolle says that the seeds are white. Loureiro, as well as De Candolle, cites also plate 137 of Rumphius (16), illustrating a plant which is described as having white flowers, white seeds, and pods broadest toward the apex, as shown by the drawing.

Dolichos cultratus Thunberg (19) is based on one of the varieties grown in Japan. The color of the flowers and seeds is not given, but the pods are acinaciform; that is, broadest toward the apex.

Lablab nankinicus Savi (17, p. 119), as described by Savi, is a variety with white flowers, ovate, turgid white seeds, and short, firm-

walled acinaciform pods, which open easily. The description is detailed, and the author evidently grew the plant he describes. Savi identifies with his species a variety from Egypt described by Alpino; one cultivated in Japan, but originally from Nankin, China, described by Kaempfer; one from Jamaica described by Sloane; and one from Jamaica and Barbados described by Plukenet. It is hardly likely that all of these are the same variety, even if they agree in the diagnostic characters set forth by Savi.

Lablab leucocarpos Savi (17, p. 120) is described as having white flowers, subglobose. black or reddish black seeds, and white, fleshy, acinaciform pods, which shrink in drying. The long, detailed description suggests a variety very similar to, if not identical with, S. P. I. No. 31363. The source of the variety is not stated, but Savi received the seed under the name *Dolichos lablab* siliqua eduli, that is, *Dolichos lablab* with edible pods.

Lablab microcarpus De Candolle (3, p. 402) is based on the plant described and figured by Rumphius (16, p. 390, pl. 141, fig. 1) under the name *Cacara litorea*. It is a seashore plant, apparently a species of *Canavalia* near to *C. turgida*.

Dolichos lignosus Linnaeus (10) is probably distinct from the bonavist, but there is much difference of opinion among botanists as to the actual identity of the plant. Linnaeus's original description and figure of *Dolichos lignosus* (9) were based on a plant, supposedly from America, that bloomed but did not fruit in Clifford's garden in Holland. It is described as perennial, woody stemmed, and with red or purple flowers. The figure shows a plant much like the bonavist, but with smaller leaflets. Linnaeus also cites as identical with his plant "*Phaseolus indicus perennis*, floribus purpurascensibus. Hort. Carolrh. 36."

In 1753, when Linnaeus (10) gave the name *Dolichos lignosus* to the plant he had described in 1737 (9), he modified his description by stating that the pods were strictly linear and that the habitat of the plant was unknown. Inasmuch as the original plant of *lignosus* in Clifford's garden did not produce pods, it would be a matter of interest to determine on what basis Linnaeus decided 16 years later that they were strictly linear.

In 1763 Linnaeus (11, p. 1022) repeats his description made in 1753 (10), but adds as a synonym, "*Cacara* s. *Phaseolus perennis* Rumph. Amb. 5, p. 378, t. 136," and "Habitat in India."

Rumphius (16, pl. 136) shows a plant, clearly the bonavist, with the immature pods nearly straight and of about the same width at base and apex, very similar to S. P. I. No. 21998 (Pl. I).

It is from this figure of Rumphius that most later writers have interpreted *Dolichos lignosus*. Rumphius's figure, however, differs

from Linnæus's original illustration (9) considerably, and one may seriously doubt whether it is the same species.

Two other illustrations of *Dolichos lignosus*, both colored, resemble Linnæus's original much more closely, namely, Smith's (18) and Curtis's (4). Each of these illustrations depicts a plant with red flowers and with small leaflets, as in Linnæus's illustration (9). The plant of Smith shows the leaflets acuminate, not acute, as drawn by Linnæus and by Curtis. Smith says the mature pods are "an inch long, a little recurved, brownish, smooth." None of these three illustrations agrees with any of the 60 varieties of the bonavist grown at Arlington Farm, and they may well represent another species. Indeed, Smith's plant may be distinct from that of Curtis. The latter was considered a new species by Don (5), who named it *Dolichos curtisii*. Smith's plant may perhaps be *Dolichos jacquinii* DC.

The opinions of many later botanists who did not have much first-hand knowledge on which to decide whether *lignosus* was really a different species from *lablab* may be disregarded. The opinions of botanists who studied the flora of India are, however, entitled to greater weight, inasmuch as both species are supposed to be from that region.

Roxburgh (15) differentiates *Dolichos lablab* from *D. lignosus* as follows:

Legumes horizontal, compressed, semilunar, with a straight scabrous back ending in a straight, daggered point---*lablab*.

Legumes linear, oblong, slightly incurved, torulose, both margins turned and rugose, with a subulate, recurved apex-----*lignosus*.

Of the former, Roxburgh cites seven varieties, with three of which he identifies plates 136, 137, and 141 of Rumphius (16). Of the latter, he lists six varieties, with one of which he regards plate 25 in Kaempfer as identical.

Plate 136 of Rumphius (16) has already been referred to.

Plate 137 gives an oblique view of full-grown pods that apparently are oblong, but probably are broadest toward the apex, as in ordinary varieties of the bonavist.

Plate 141 is clearly a species of Canavalia.

Plate 25 of Kaempfer (7) has the immature pods falcate, while the mature ones are nearly straight and not broader toward the apex; in other words, they are linear and not different in form from those on plate 136 of Rumphius (16), except that the tip is incurved. Judging from the plates cited, Roxburgh seems to have given great weight to the form of the tip of the pod, but this character is of little significance. In our opinion, plates 136 and 137 of Rumphius (16), as well as plate 25 of Kaempfer (7), all clearly represent the

bonavist. The pod forms depicted show much less divergence from one another than in undoubted varieties of bonavist grown at Arlington Farm.

Prain (14) thinks that Roxburgh reversed the incidence of the Linnæan names, partly because he cites plate 136 of Rumphius (16) as representing *Dolichos lablab*, when as a matter of fact the same plate is cited as *D. lignosus* by Linnæus in 1763 (11, p. 1022).

Prain further states that the two can be distinguished by the following characters:

Dolichos lablab L. Pods longer, more tapering at point; seeds with long axis parallel to sutures.

Dolichos lignosus L. Pods shorter, more abruptly truncated at end; seeds with long axis at right angles to sutures.

On the basis of these pod characters, S. P. I. Nos. 8356, 25132, 21998, and 17534 would be *Dolichos lablab* and 27533 and 31363 would be *D. lignosus* (compare Plate I), but in all these varieties the long axis of the seeds is at right angles to the sutures. If the description of Prain (14) of the position of the seeds is correct in what is designated as *D. lablab*, then all of the plants tested in our studies are *D. lignosus*.

On the whole, the writers incline to the view that two species can not be differentiated on the basis of the characters ascribed by Roxburgh (15) and by Prain (14). It seems doubtful, indeed, whether any of the varieties discussed by these botanists represents the *Dolichos lignosus* of Linnæus.

The plant cultivated as an ornamental in California under the name *Dolichos lignosus* is in reality *Dolichos jacquinii* DC.

NOTES ON THE INTRODUCTION NUMBERS OF DOLICHOS LABLAB.

The following notes refer to the various introductions of *Dolichos lablab* made by the Office of Foreign Seed and Plant Introduction from 1899 to 1913.

The 95 lots here enumerated represent at least 50 varieties, judging partly by the seeds. At Arlington Farm, Va., 57 lots representing 39 varieties were grown from one to four seasons, and full comparative field notes of these were secured. Twenty-five of these are early enough to mature and two to blossom. Twelve are so late that they had not even formed buds before they were killed by frost.

2083. From Paris, France, 1899. See No. 20447.

2882. From Wuchang, China, 1899. No data preserved.

3286. From Algeria, 1899. Chinese white-flowered No. 1. Seeds apparently identical with No. 20447.

3287. From Algeria, 1899. Chinese white-flowered No. 2. Seeds quite the same as No. 3286.

3288. From Algeria, 1899. Chinese white-flowered No. 4. Seeds indistinguishable from No. 3286. Apparently all three are the same as No. 20447.
3597. From Smyrna, 1899, under the name "Saliakakia." Seeds dark red with black spots. No cultural notes.
4378. From Naples, Italy, 1900, erroneously labeled *Pachyrhizus tuberosus*. Seeds dark reddish, just like No. 5040.
4380. From Naples, Italy, 1900. Probably the same as No. 20447.
4383. From Naples, Italy, 1900, under the name *Dolichos atropurpureus*. This is a bushy variety of only medium vigor, when planted in rows growing to a height of 18 to 24 inches, with vining branches 3 to 4 feet long; herbage dark purple; flowers numerous, in erect panicles; pods dark purple, broad, 1.5 inches long, somewhat fleshy, the first maturing in about 100 days; seeds small, dark purple to nearly black. This variety is quite ornamental in its purple foliage, and is apparently identical with the colored plate of *Dolichos purpureus* L. in the Botanical Register, vol. 10, plate 830. At Arlington Farm it readily volunteers year after year where once planted.
4384. Received from Naples, Italy, 1900, under the name *Dolichos semper-virens*. A viny variety making a dense mass of herbage 3 feet deep; stems purple; leaflets green; flowers purple, on short peduncles; immature pods green, broad, 1.5 inches long, the first maturing in 100 days; seeds compressed, small, varying from dark purple to nearly black.
- For forage purposes this variety is one of the most satisfactory, on account of its vigorous growth, bushy habit, and the abundance of pods which it produces. These pods are not fleshy, and they mature without shrinking. This variety volunteers more abundantly than any other. No. 25160, from a stray plant at Arlington Farm, differs only in the color of the seeds, these being reddish with black marblings. No. 22025, also the progeny of a stray plant, is identical with No. 4384.
5040. From Naples, Italy, 1900, erroneously labeled *Pachyrhizus tuberosus*. Seeds identical with No. 4378. Notes insufficient, but plants were too late to bloom at Arlington Farm.
5070. From Hawaii, 1900, but originally from Australia under the name "tongan bean." Seeds large, nearly black, with a few buff specks. No cultural notes preserved.
5402. From Calcutta, India, 1900, erroneously labeled *Canavalia virosa*. Seeds large, black. No cultural data.
5412. From the Royal Botanic Gardens, Calcutta, 1900, under the name *Dolichos lablab falcatum majus*. Seeds black purple, medium sized. No cultural data.
5413. From same source as preceding, under the name *Dolichos lablab falcatum minus*. Seeds medium sized, dark purple. No cultural notes.
5414. From same source as No. 5412, under the name *Dolichos lablab purpurascens*. Seeds dark reddish purple. No cultural notes.
5519. From Lombok, Dutch East Indies. 1900, under the name "Katjang ussi." Seeds large, black purple. No cultural notes.
6319. From Tokyo, Japan, 1901. Seeds red purple, indistinguishable from No. 20447. No field notes.
6320. From Tokyo, Japan, 1901. Seeds dark purple, medium sized. No cultural notes.

6377. Progeny of No. 2083.
6569. From China, 1901. Seeds black purple. No field notes.
8258. From Nice, France, 1902. No further data.
8355. From Morioka, Japan, 1902. A vigorous variety, the plants in 3-foot rows growing 24 inches high and 30 inches broad; stem and petioles purplish; leaflets green; flowers purple; pods falcate, broadest at apex, 4 inches long, fleshy, green with purple margins, the first maturing in about 120 days; seeds purple black. Very similar to No. 31716, but the pods are broader and the seeds somewhat larger.
8356. From Morioka, Japan, 1902. Rather viny, the plants growing to a height of 24 to 30 inches and making a solid mass; stems and branches purple; leaflets green, but purple veined; flowers purple, numerous, on short, erect peduncles; immature pods falcate, somewhat fleshy, reddish purple, $4\frac{1}{2}$ inches long, shrinking irregularly at maturity, the first ripening in about 115 days; seeds large, plump, nearly black. One of the most ornamental sorts. No. 25155, from Shanghai, China, is not distinguishable.
8357. From the same source as the preceding, with which it proved to be identical.
8545. From Nagpur, India, 1902. No cultural data. Seeds like No. 8686.
8686. From Surat, India, 1902. Half bushy when planted in 3-foot rows, growing to a height of 30 inches; herbage pale green, somewhat hairy; flowers white, on short peduncles; pods green at first, broad, 2 inches long, the first maturing in 110 days; seeds rather small, compressed; nearly white, excepting the micropyle and the strophiole, which are purple.
- Identical with this is No. 28032, from Poona, India, received under the name of "kadra wal." Nos. 8545 and 13373 from Nagpur, India, have identical seeds and are probably the same variety.
9431. From Nice, France, 1903. No notes or specimens of this number.
13373. From Nagpur, India, 1903. Seeds identical with No. 8686.
13374. From United Provinces of Agra and Oudh, India, 1903. Seeds identical with No. 8686.
13376. From Bombay, India, 1903, under the name "val." Notes insufficient.
17534. Progeny of No. 4383.
17884. From Peking, China, 1906. Plants very viny, 20 inches high, 40 inches broad; stems and petioles purple; leaflets green, purple veined; flowers purple, on short, erect peduncles; pods falcate, 4 inches long, green with purple margins, somewhat fleshy, the first maturing in about 115 days; seeds black purple. Very similar to No. 31716, but apparently a little later.
17885. From Hawai-jou, China, 1906. Seeds black purple or somewhat spotted. Cultural notes insufficient.
18448. From Shanghai, China, 1906. Seeds identical with No. 21998, but none germinated.
18746. From the Bahamas, 1906. Seeds dark brown; flowers purple. No cultural notes.
18747. From the Bahamas, 1906. Seeds white; flowers white. No cultural data.
20447. "Stringless," from Vilmorin-Andrieux & Cie., Paris, France. A vigorous, very viny sort when planted in 3-foot rows, making a solid mass of herbage 30 inches deep; herbage green; leaflets large; flowers rather large, white, in compact panicles, on short peduncles; immature pods

20447—Continued.

very flat, broad, 4 inches long, fleshy, white, shrinking in maturing, the first ripe in 110 days. Seeds large, plump, reddish purple in color.

Other lots from the same source are Nos. 2083, 6377, 25256, and 31363. No. 4380, from Naples, is seemingly the same variety, judging from the seeds and the brief notes recorded.

The green pods of this variety make a most excellent vegetable, very similar to snap beans, but even more delicate in flavor. This variety should be grown largely as an arbor vine, as it is not only ornamental, but also produces an abundance of delicious beans.

A number of other lots introduced, concerning which no notes have been preserved, but which have similar seeds, are Nos. 3286, 3287, and 3288, from Algeria, received under the name "Madagascar bean"; No. 6319, from Tokyo, Japan; and Nos. 25727 and 25728, from Baroda, India.

20891. From Kobe, Japan, 1907, under the name "fujimame." A vigorous variety with green foliage; flowers white; pods white, somewhat fleshy, the first maturing in about 120 days; seeds large, plump, dark purple. This variety closely resembles No. 25158, but that has cream-colored, much smaller seeds.

21352. From Teyhampett, Madras, India, 1907. A very viny sort, which sprawls on the ground; herbage green; late, no flowers being produced at Arlington Farm after 130 days; seeds cream color, quite large, much compressed, distinct from any other sort with cream-colored seeds received.

21947. From Buitenzorg, Java, 1908, under the name "katjang ieda." A moderately vigorous, late, viny variety; stems purple; leaflets green; flowers pale purple; no pods maturing at the end of 130 days; seeds medium sized, dark purple to black, somewhat compressed.

21948. From Buitenzorg, Java, 1908, under the name "katjang ypit." A vigorous late variety, barely coming into bloom at Arlington Farm in 130 days; flowers pink purple; no pods formed; seeds medium sized, rather plump, dark reddish purple.

21949. From Buitenzorg, Java, 1908, under the name "katjang idjo." A very late purple-stemmed variety that did not bloom at Arlington in 1908. Seeds medium sized, purple black.

21950. From Buitenzorg, Java, 1908, under the name "katjang ypit poetih." Very similar to the preceding when grown side by side. Seeds indistinguishable.

21998. From Boshan, Shantung, China, 1908. An early, not very vigorous variety; plants growing about 30 inches high and as broad, rather bushy, a few of the branches vining to a length of 3 or 4 feet; foliage green; flowers white, on long, stout peduncles; immature pods somewhat fleshy, pale, 2.5 inches long, shrinking and becoming somewhat distorted when maturing, the first pod ripening in about 100 days; seeds subglobose, cream colored, with the micropyle, the strophiole, and a few spots on the back purple.

Apparently identical with this are Nos. 25152 and 25153, both from Shanghai, China. No. 18448, from Shanghai, China, has identical seeds, but these did not germinate.

22025. Progeny of a stray plant, Arlington Farm, identical with No. 4384.

22934. From Karlsruhe, Germany, 1908. A slender, sprawling variety, with green stems and leaves; flowers purple, the first pods maturing in about 110 days; seeds small, dark purple to black.

23215. From Tangsi, China, 1908. A very late, viny variety, which barely comes to bloom in 130 days; herbage green; flowers white; seeds subglobose, entirely cream colored.
- Apparently identical with this variety are No. 25440, from Yachow, China, where it is called "beh pien dou," and No. 24912, from Herradura, Cuba. No. 25915, from Hangchow, China, has identical seeds, but these did not germinate.
23329. From Canton, China, 1908. Seeds cream colored; flowers white. Grown only one season; notes too brief for identification.
23330. From Canton, China, 1908. Seeds dark red purple; did not germinate.
- 23953 to 23956. From Peking, China, 1908. Seeds of No. 23953, black purple; of No. 23954, dark reddish; of No. 23955, red; of No. 23956, cream colored, identical with those of No. 27195. No cultural notes were obtained from these four lots.
24912. From Herradura, Cuba, 1909. This variety proved indistinguishable from No. 23215.
24913. From the same source as the preceding. Very viny and late, not blooming at Arlington Farm in 1909. Seeds reddish chestnut, rather small.
24914. From the same source as the preceding. In habit and maturity not different from No. 24913, but seeds large, plump, and nearly black.
25018. From Khartum, Egyptian Sudan, 1909. A very late, vigorous variety, not blooming at Arlington Farm in 1909. Seeds medium sized, compressed, varying in color from dark purple to nearly black.
25132. From Soochow, China, 1909. A vigorous variety, producing a dense mass of herbage $2\frac{1}{2}$ feet deep; stems and petioles purple; leaflets green with purple veins; blossoms numerous, purple, and in large, erect panicles; immature pods falcate, flattened, green with purple margins, 3 inches long, the first maturing in about 130 days; seeds medium sized, subglobose, black. This variety has foliage and pods very similar to No. 17884, but is later.
- 25152 and 25153. From Shanghai, China, 1907. Both proved to be identical with No. 21998.
25154. From Shanghai, China, 1907. Not very vigorous; herbage green; flowers pale purple; pods falcate, white, somewhat fleshy, shrinking when dry, barely maturing in 130 days; seeds plump, dark purple. This variety agrees very closely with Jacquin's illustration of *Dolichos benghalensis* in Hortus Botanicus Vindobonensis (6).
25155. From Shanghai, China. Grown in 1908 and 1909. Identical with No. 8356.
25156. From J. M. Thorburn & Co., New York, 1906. Very similar in growth, appearance, and maturity to No. 25157. Seeds slightly larger, more compressed, and cream colored except for a purple line at the margin of the hilum. Identical with this variety is No. 27531, from Naples, Italy, received as *Dolichos lablab* var. *albus*.
25157. From British Guiana, 1907. Half bushy, when planted in 3-foot rows, making a solid mass 36 inches deep; branches 3 to 5 feet long; herbage wholly green; flowers white, on short peduncles; immature pods green, not fleshy, broad, 1.5 to 2 inches long, not shrinking at maturity, the first pod ripening in about 115 days; seeds very small, somewhat compressed, entirely cream colored.
25158. From Barbados, 1908. Bushy, not at all vining when planted in 3-foot rows, each plant about 30 inches high and as broad; herbage green; flowers white, on short peduncles; very fruitful; the immature pods

25158—Continued.

- fleshy, white, not distorted when dry, falcate, 2 to 2½ inches long, only one-half inch wide, straw colored; seeds very small, entirely cream colored, the first maturing in 100 days. Seeds very similar to No. 25157, but pods very different.
25159. From a stray plant at Arlington Farm of unknown origin, 1907. A moderately vigorous variety, producing a mass of herbage 2½ feet deep and as broad; leaves green; flowers on rather stout peduncles; immature pods white and somewhat fleshy, the first maturing in about 100 days; seeds rather small, plump, reddish purple.
25160. Same source as the preceding. Identical in all respects with No. 4384.
25256. From Paris, France, 1909. Identical with No. 20447 in all respects.
25440. From Yachow, China, 1909. Seeds indistinguishable from No. 23215, and the field notes indicate no difference.
25648. From Yachow, China, 1909. Very viny, the branches 6 feet long or more, sprawling, stems purple; leaflets purple veined; flowers purple, on very short peduncles; pods falcate, fleshy, green, with purple margins, 3 inches long, shrinking much in drying; barely maturing in 120 days; seeds purple black, medium sized, plump. This resembles both Nos. 8356 and 31716, but is distinct from both.
25648. Mixed with the preceding. A bushy variety, 2½ feet high; stems and foliage green; flowers white, on short peduncles; pods whitish, fleshy, becoming slightly distorted when dry, 3 inches long, the first maturing in about 120 days; seeds large, plump, black.
- 25726 to 25728. From Baroda, India, 1909. Seeds of No. 25726, black purple; of Nos. 25727 and 25728, dark purple. No cultural notes for these numbers. The seeds of the first two closely resemble No. 20447.
25915. From Hangchow, China, 1909. Seeds cream colored, quite like those of No. 23215. None of them germinated.
26358. From Malkapur, Berar, India, 1909. Bushy in habit, growing to a height of 3½ feet, forming a dense mass; stems green; leaves whitish, owing to the pubescence; flowers white, on short peduncles; young pods green, broad, 2½ inches long, not shrinking, the first maturing in about 110 days; seeds small, much compressed, tan colored.
27195. From Shanghai, China, 1910. Somewhat bushy when planted in 3-foot rows, forming a solid mass 3 feet deep; herbage green; flowers white; immature pods green, somewhat fleshy, the first maturing in about 140 days; seeds plump, subglobose, cream colored except for the micropyle and strophiole, which are purple. The seeds of this variety resemble very closely No. 21998, but lack the purple spots on the back. The pods, too, are quite different, and the plant is considerably later. No. 23956, from Peking, China, has identical seeds, but no field notes concerning this number are at hand.
27531. From Naples, Italy, 1910. This has proved to be indistinguishable from No. 25156.
27532. From Naples, Italy, 1910, under the name of *Dolichos lablab* var. *atro-purpureus*. Stems purple; flowers purple; seeds just like No. 4384, with which it is probably identical, judging from insufficient notes.
27533. From Naples, Italy, 1910. A very viny variety, producing a mass of herbage 2 feet deep and vines 6 to 8 feet long; stems and petioles purple; leaves dark green, purple veined; flowers purple, on short, erect peduncles; pods bright, shiny purple, broad, 2½ inches long, slightly fleshy but retaining their form when dry, the first maturing in

27533—Continued.

about 110 days; seeds medium sized, plump, dark purple to nearly black. This variety is exceedingly ornamental, especially in its bright purple pods.

27678. From Goa, India, 1910. No field notes. Seeds large, dark purple to nearly black, very similar to those of No. 27533.

27882. From Malkapur, Berar, India, 1910. No cultural data and no seeds preserved.

27883. From same source as preceding. Very viny, but too late to bloom at Arlington in 1910. No seeds preserved.

28032. From Poona, India, 1910. Plants vigorous, rows becoming 3 feet high and 40 inches broad; herbage green, pale, with short pubescence; flowers white, in a small panicle; pods green, not shrinking when dry, broad, compressed, 2 inches long, the first maturing in 120 days; seeds small, somewhat compressed, cream colored, with a purple margin about the hilum and a purple spot on the micropyle and on the strophiole. Very similar in all respects to No. 8686, but larger and later.

28033. From Poona, India, 1910. A very viny, very late variety that did not bloom at Arlington Farm in 1910 in 126 days. Seeds cream colored, with the micropyle and the strophiole purple.

28736. From Nairobi, British East Africa, 1910. A very vigorous late variety, with green herbage, not blooming at Arlington Farm in 1913. Seeds large, plump, reddish chestnut.

31363. From Paris, France, 1911. Same as No. 20447.

31716. From the Philippine Islands, 1911, where it is called "batao." An early variety, when planted in 3-foot rows making a mass of herbage 18 to 22 inches deep; stems and petioles purple; leaflets green, with purple veins; flowers purple, in short, erect panicles; immature pods, 4 inches long, green, with purple margins, falcate, somewhat fleshy, the first maturing in about 110 days; seeds large, mostly black, but some of them reddish, marbled with black.

This variety is commonly grown in Philippine villages as a vegetable. At the Lamao Experiment Farm, near Manila, the vines persist for two years. This closely resembles Nos. 8355 and 17884, but all three are different.

31729. From Canton, China, 1911. Seeds subglobose, entirely cream colored. No field notes.

32610. From Trichinopoly, India, 1911. Very vigorous and viny, but not blooming at Arlington Farm in 1913. In growth and appearance, as well as in seed characters, indistinguishable from No. 35352.

34106. From Pacasmayo, Peru, 1912, under the name "yuna bean." A very vigorous late variety, producing a mass of herbage $3\frac{1}{2}$ feet deep when planted in 3-foot rows; herbage green; leaflets very large; very late, not blooming in 130 days; seeds entirely cream colored, medium sized, different from any other lot received.

34501. From Seharunpur, India, 1912, under the name "makhan sem." A very viny variety when planted in 3-foot rows, making a mass of herbage 2 to $2\frac{1}{2}$ feet high; foliage green; flowers white, large, on long, stout peduncles; pods falcate, fleshy, white when immature, $3\frac{1}{2}$ inches long, none maturing in 120 days; seeds reddish brown.

35351. From Bangalore, India, 1913. In habit and general behavior indistinguishable from No. 34106, but the seeds are different, being quite like those of No. 27195.

35352. From Bangalore, India, 1913. Indistinguishable in growth and maturity from No. 35351. Seeds medium sized, cream colored, with a purple spot at each end of the hilum.
35353. From Mysore, India, 1913. In appearance and maturity not distinguishable from No. 34106, but the medium-sized seeds are not compressed and are reddish chestnut in color.
35354. From Bangalore, India, 1913. In growth and maturity not different from No. 34106. Seeds subglobose, buff colored, medium sized.
02126. From Matamma, Egypt, 1914. A very vigorous viny variety, making a row mass 30 inches deep and 4 to 5 feet broad; herbage entirely green; flowers white, rather small; panicles 8 to 12 inches long, pyramidal, many flowered; pods (immature) falcate, 3 inches long, one-half inch broad, half fleshy, green when fully grown but not mature; seeds small, purple, rather plump; very late, not maturing in 130 days.

This is the only variety secured from Egypt, where the bonavist was first described. This variety does not answer to that originally described by Alpino, nor to the variety *hortensis* described by Schweinfurth and Muschler.

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A. D. MELVIN, Chief



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PROFESSIONAL PAPER.

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FERMENTED MILKS.

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INTRODUCTION.

Within recent years there has been a rapidly growing interest in the therapeutic value of buttermilk and other fermented milks, such as kefir, kumiss, and yogurt. This is seen in the increasing sale of buttermilk, in the large number of special preparations now offered for sale, and in the frequent discussion of this subject in popular and scientific publications. Buttermilk is not only consumed in large quantities as a beverage, but is recommended by physicians as a therapeutic agent in the treatment of intestinal disorders, and is in constant use in many hospitals.

It is the aim of this paper to give the reader a brief résumé of our present knowledge of this subject. The literature relating to fermented milks is already voluminous, and few persons, not even physicians, are so situated that this can be brought together and assimilated. It will be necessary for the benefit of those having a professional interest in the subject to include information of a somewhat technical nature.

All the more familiar fermented milks are the result of an acid fermentation in which the sugar of the milk is split up into lactic acid. This may be brought about by the presence in the milk of varieties of the common lactic-acid group of bacteria, or, as in the case of yogurt, by special organisms; or a yeast may be present, adding an alcoholic to the ordinary acid fermentation.

In many large cities special fermented milk preparations can be obtained under various trade names, such as zoulak, vitallac, yogurt, matzoon, bacillac, kefir, kumiss, and lacto-bacilline. These are all soured milks which have been introduced from southern Russia, Turkey, and neighboring countries. They are sold as freshly prepared milk, or in the form of tablets or powders in capsules which may be taken as such or used to ferment milk. These preparations have been widely advertised and are the subject of very positive statements in regard to the benefits derived from their use.

THERAPEUTIC VALUE OF FERMENTED MILK.

Fermented milks have been used ever since very early times, but it is only within very recent years that physicians have become interested in the possibilities of their use for therapeutic purposes. Within the past 20 years there has been an increasing number of papers in the medical journals on this subject, and at one time the widespread popular interest in fermented-milk therapy was reflected by the numerous magazine and newspaper articles on various phases of the subject. This interest was stimulated in a large measure by the work of Metchnikoff (58)¹ and his associates. His views, which are set forth in some detail in Chapter V, "Lactic acid as inhibiting intestinal putrefactions," of his book entitled "The Prolongation of Life," are looked upon by the more conservative investigators of this country as overdrawn and as unsupported by experimental evidence. In this book great stress is laid on the longevity of the people of certain countries in which fermented milks are an important part of the diet.

In considering evidence of this kind it should be remembered that many other things may contribute to the general health and vigor of the people and that these factors can not be excluded in drawing the conclusions. The people who habitually consume large quantities of fermented milk usually live a simple life, largely in the open air, and we have no means of knowing how much this may have contributed to the vigorous old age frequently observed among them.

The use of fermented milks as a therapeutic agent is based on the assumption that they are able to combat the so-called autointoxication caused by the undue accumulation in the body of toxic substances emanating from the intestinal tract. The theory of auto-intoxication may be stated briefly as follows: The digestive tract of the human being is at birth free from bacteria, but in various ways, chiefly through the food, many kinds of bacteria are introduced into the alimentary canal. In the intestines and particularly in the large intestine some of them find favorable conditions for growth and be-

¹ Figures in parentheses refer to the bibliography at the end of this bulletin.

come established there in large numbers. In the normally nourished infant the bacterial varieties are limited in number and for the most part consist of acid-forming types which by the active fermentation of the milk sugar furnished in large quantities in the food produce conditions under which bacteria of the putrefactive type are unable to multiply to any extent. The predominance of an acid fermentation in the large intestine produces an acid stool with a characteristic but comparatively unobjectionable odor. As the child gets older the variety of food is greater and the relative proportion of carbohydrates to protein is much reduced. In place of the acid fermentation there is a decomposition of the protein by other bacteria, intestinal gas is produced, and the stools become alkaline and frequently have a very objectionable odor. In the bacterial decomposition of the predigested protein it is supposed that products of a more or less toxic nature are produced. When the quantity of these products is relatively small they are disposed of through the normal channels and have no appreciable effect. If the excretory system fails to do its normal work, or if the protein decomposition is unusually active, toxic substances accumulate and the symptoms of autointoxication are produced. The production of toxic substances in abnormal amounts may be caused by a combination of circumstances promoting an unusual activity of putrefactive bacteria normally present, or it may be because the bacterial flora of the intestines changes and new bacteria are introduced.

The method of treating this condition by the use of sour milk is based on three conditions which may be stated as follows: (1) It assumes as correct the theory of the production of toxic substances in the intestine by the action of bacteria in quantities sufficient to cause the symptoms of autointoxication; (2) the putrefaction or fermentation through which these toxic substances are produced can be suppressed by other bacteria; and (3) the bacteria which it is proposed to use in suppressing the putrefactive bacteria may be introduced into the intestines and will be able to establish conditions there under which they will multiply and persist, while the objectionable types are driven out.

The standing of the theory of autointoxication mentioned under the first condition can not be discussed in detail in a paper of this nature. It may be said, however, that the question of autointoxication, in its broader sense, is not nearly so simple as it is stated here. It is at best only a theory, and much investigation of details will be necessary before its position can be determined.

The second condition is easily demonstrated, not only by scientific observation, but also by many instances in our daily life. Vinegar, which is used in pickle making, owes its preservative action to the

acetic acid produced by a bacterial fermentation; when milk sours spontaneously, the acid-forming bacteria develop acid so rapidly that in a short time all other bacteria are inhibited. Observations of this kind could be multiplied almost indefinitely. In fact, in the bacterial world, as among the higher plants in their natural state, there is a constant struggle for mastery in which the types best suited to their environments, or, perhaps more correctly, less sensitive to the unfavorable conditions which they themselves produce, gain the ascendancy and more or less completely suppress other forms.

The particular bacterium which it is proposed to use in suppressing the putrefactive bacteria of the intestines is the organism commonly known as *Bacillus bulgaricus*, or the Metchnikoff bacillus. It is characterized by its ability to form acid in exceptionally large amounts from sugars, particularly milk sugar.

When milk containing bacteria of this type is held under conditions favorable to its growth, the acid produced will inhibit other forms and the milk will eventually become a practically pure culture of the *Bacillus bulgaricus*. There can be no question that, under conditions favorable to its growth, this bacterium is able to suppress very effectively other kinds of bacteria, even many of those which produce an acid fermentation. This is well illustrated in the manufacture of cheese of the Emmental or Swiss type. Cheese made by this method from milk containing gas-forming bacteria will become filled with gas bubbles in the press. If a comparatively small amount of a culture of the *Bacillus bulgaricus* is added to this milk the high temperature at which the cheese is held promotes its vigorous development, and the gas formers are completely suppressed.

There is little doubt that if this organism could be established in the large intestine under conditions favorable to its growth it would soon produce a state of affairs which would at least inhibit the growth of the bacteria that usually decompose the proteins. The evidence that this takes place, even when large quantities of the bacteria are ingested, is by no means conclusive. On the one side the associates of Metchnikoff have produced considerable evidence to show that when *B. bulgaricus* is taken into the digestive system it becomes established in the intestines, where it persists for some time after the feeding ceases. Cohendy (12), who fed four patients for extended periods on milk curdled with *B. bulgaricus*, concluded that this organism was readily established in the intestines and that it persisted there for a considerable time after the subject had ceased to take fermented milk. This was said to be especially true if a diet containing suitable nourishment for the ingested organism was adopted. It is stated that the multiplication of these bacteria took

place in the upper two-thirds of the colon. The stools were acid or neutral.

The same writer in another paper (14) shows that intestinal putrefaction as indicated by the excretion of ethereal sulphates in the urine was materially reduced by the addition of a sour milk to the diet and that this reduction, which may reasonably be attributed to a disinfection of the large intestine, continued after the ingestion of sour milk was discontinued. This may be taken as an indication that the growth of the bacteria continued after their introduction ceased. This disinfecting action of the lactic-acid culture was not appreciably influenced by variations in the amount of sugar eaten, indicating that the ordinary diet contains sufficient sugar to support the growth of the lactic-acid bacteria in the intestine.

Belonovsky (3) arrived at somewhat similar results in experiments in which mice were fed a basic ration of sterilized grain and water. Mice which received in addition milk cultures of *B. bulgaricus* for one and one-half months showed this organism in the droppings 15 days after the last feeding. When the milk cultures were fed for four months *B. bulgaricus* was present in the droppings for four weeks after the last feeding. He states that the bacteria in the droppings, especially the gas-forming bacteria, were very much reduced by feeding *B. bulgaricus*, but were not affected by the addition of the basic diet of sterile milk or milk curdled with lactic acid.

Many experiments of a similar nature could be quoted, as well as clinical observations, tending to show that the ingestion of milk cultures of *B. bulgaricus* reduces or eliminates evidences of intestinal putrefaction. On the other hand, Herter (41) found that in the digestive tract of a monkey, killed after feeding for two weeks on milk soured with *B. bulgaricus*, this organism was abundant in the upper part of the small intestine only. In the lower part and in the large intestine *B. bulgaricus* was present in only moderate numbers as compared with other bacteria.

Rahe (70), in a recently published paper, maintains that the difference between the *B. bulgaricus* and certain acid-forming bacteria, which are known to occur normally in the intestines, is so slight that they can be distinguished only with difficulty, and he suggests that belief on the part of some investigators that *B. bulgaricus* becomes established in the intestines was caused by their inability to distinguish between these two types. His work tends to show that while the *B. bulgaricus* appears in the feces during the feeding, it persists for only a few days after the ingestion of cultures ceases.

The situation may, perhaps, be fairly summed up by saying that while there is no conclusive evidence that *B. bulgaricus* is able to establish itself in the intestines in such a way that other bacteria are driven out, it is undoubtedly true that in many cases marked improve-

ment has resulted from the ingestion of milk cultures made from it. It is by no means certain, however, that the results which have been obtained by the use of milk cultures have been attributable to any peculiar virtue in the organism itself. It has been held by some investigators that the intestinal flora may be radically changed by a fundamental change in the diet.

Distaso and Schiller (19) state that when rats were fed a diet of lactose and dextrine the heterogeneous intestinal flora was changed to one consisting almost exclusively of *Bacillus bifidus*, the characteristic acid-forming bacillus of the intestines. This is in accord with the earlier work of Herter and Kendall (43), who found that the nature of the bacterial flora of the intestines could be promptly and distinctly changed by a radical change from a diet high in protein to one in which carbohydrates predominated, or vice versa. A high-protein diet caused symptoms of intestinal putrefaction. A change to a carbohydrate diet resulted in a reduction of the putrefactive bacteria, an increase in the acid-forming bacteria, and the disappearance of the indications of autointoxication. Similar results were obtained in an investigation carried on by Rettger (71).

This work was very comprehensive, covering a long series of experiments with chickens and white rats, and the results if accepted will make it necessary to revise the commonly accepted views of the physiological actions of sour milk. Rettger found that when chicks were fed milk not only was the per cent of mortality materially reduced, but the rate of growth was greatly increased. Practically the same results were obtained whether sweet or sour milk was fed, and there was no appreciable difference in the results obtained by feeding milk soured by *Bacillus bulgaricus* and the common lactic forms. The probable explanation of this fact was found in the experiments with white rats, in which a study was made of the intestinal bacterial flora during the feeding experiments. It was found that when the rats were fed a diet which included milk, the usual mixed bacterial flora of the intestines was replaced almost completely by two types of bacteria which resemble the *Bacillus bulgaricus* very closely, especially in their physiological characteristics. Identical results were obtained when the milk was displaced in the diet by milk sugar.

The conclusion seems obvious. The bacteria of the high-acid type, which are apparently normally present in the intestines, are stimulated by the unusual amount of milk sugar furnished by the milk diet, and multiply to such an extent that the ordinary mixed flora is suppressed.

The beneficial effect of a sour-milk diet is attributable, perhaps, not so much to the bacteria contained in the milk as to the milk itself, which provides material for an acid fermentation in the intestines.

Milk is usually looked upon as a nitrogenous food, but it should be remembered that it contains about 5 per cent of lactose, a carbohydrate which seems to be peculiarly adapted to bacterial fermentation.

Aside from the possible therapeutic value of fermented milks, there can be no question that they are nutritious and refreshing and that their use should be encouraged for their food value.

FOOD VALUE OF FERMENTED MILK.

The high food value of milk is too generally recognized to need discussion here; fermented milks also have a high food value, except that in some cases the fat is partially or entirely removed. Otherwise the food value of the fermented milk differs little from that of the fresh milk from which it is made. Any increased digestibility of the fermented milk is due not so much to change in the chemical nature as to the fact that the casein is furnished in a precipitated and finely divided condition. In none of the fermented milks is there any material cleavage of the casein resembling the digestion in the stomach. The fat is practically unchanged, and a part only of the sugar is converted into acid, alcohol, or gas. In certain gastric troubles in which it is difficult to find any food that can be retained by the patient, fermented milks are frequently used with good results. Kefir and kumiss especially are used under such circumstances, as the stimulating action of the carbon dioxid which they contain is believed to aid in their digestion. To the physician the value of a highly nutritious food which can be digested when other foods are rejected is obvious.

There are many questions that should be very carefully considered before a fermented milk is introduced as an important part of the diet. As Herter (41) has pointed out in the admirable paper already cited, the addition of fermented milk to the diet may change very materially the ratio of protein to other classes of food. If the milk is taken in place of other food, the daily protein ration may be so reduced that intestinal putrefaction, which is dependent on the protein part of the food, is diminished. On the other hand, if milk is added to the usual food, the protein ratio may be increased rather than diminished. In many cases the condition of the mucous membranes will not permit the presence of organic acid, and soured milk can not be retained. It is also possible that symptoms of autointoxication are not caused by unusual bacterial activity in the intestine, but by functional failure of certain organs. This point could be determined only by a physician. It would be very unsafe to consume large quantities of milk, fermented or unfermented, under certain pathological conditions. In any case an important change in the diet should be made only upon the advice of a physician.

THE VARIOUS FORMS OF FERMENTED MILK.

If it is considered advisable to use cultures of acid-forming bacteria, the form in which they are taken becomes an important question. In large cities one usually has a choice of lactic-acid bacteria from several sources. Buttermilk is usually available, although it is not always of good quality. Sometimes kumiss or kefir can be obtained, and at the present time milk coagulated with the so-called Metchnikoff bacillus is sold as yogurt or matzoon and under various trade names.

CULTURES IN TABLET AND CAPSULE FORM.

In addition to these freshly prepared preparations several tablets or capsules purporting to be pure and active cultures of the *Bacillus bulgaricus* are now offered for sale. These are for use in fermenting

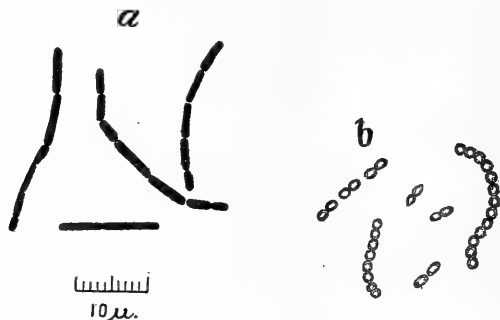


FIG. 1.—Organisms causing fermentation of milk.
a, *Bacillus bulgaricus*; b, lactic-acid bacteria.

milk or are to be taken directly in place of buttermilk or yogurt. Herschell (39) in his little book on the therapeutic uses of soured milks recommends the use of these preparations in preference to fermented milk, but it should be noted that he is very explicit in his statement that great care should be taken to determine the abundance and purity of the desired organism. *Bacillus bulgaricus* seems to be particularly sensitive to desiccation. When preparing the material in tablet form, therefore, a high percentage of the organisms is usually killed, whereas foreign organisms commonly retain their viability. Even when prepared with the best of care, such tablets lose their efficiency so quickly that unless such tablets are used within a time limit of efficiency guaranteed by the maker the results may be disappointing.

It is very easy to test the purity and activity of these dried cultures. Thoroughly pasteurize a small quantity (about half a pint) of milk by holding it, in a bottle plugged with cotton, at or near the boiling point for an hour or more. When this has cooled add two or three of the tablets and keep in a very warm place overnight. It should

not be below and may be a few degrees above blood heat. If in this time the milk has not curdled with a sharp, acid taste and without gas bubbles and whey there can be no reason for using these tablets except the possibility that they contain the active element of the culture which retards the growth of other bacteria. The evidence on this point is so inconclusive that it need not be considered in this connection.

All reliable manufacturers now place the date of manufacture on each package and state the time within which the tablets should be used.

BUTTERMILK.

Buttermilk, properly speaking, is the by-product resulting when milk or cream is churned for butter. It is the milk remaining after the fat which collects in granules is removed. If cream is churned when sweet the buttermilk does not differ from ordinary skimmed milk, but if it is churned when sour—the usual practice—the acidity is sufficient to coagulate the casein in the cream. In the churning process this curd is broken up into very fine particles. These curd particles settle very slowly, and if the buttermilk is agitated occasionally it will retain its milky appearance. When the buttermilk is allowed to stand undisturbed for several hours the curd particles sink to the bottom, leaving an opalescent whey at the top. At the present time a large part of the so-called “buttermilk” sold in cities is not buttermilk, properly speaking, since it is not made by churning cream, but is simply soured skimmed milk which has been churned or stirred in order to break up the curd. The same product is sold also under the name of “ripened milk.”

The souring of milk or cream is brought about by the activity of certain bacteria which form lactic acid by decomposing the milk sugar (lactose). The ability to form acid from lactose and other sugars is possessed by many kinds of bacteria, but is so characteristic of a certain group that they are commonly spoken of as the lactic-acid bacteria. (See Fig. 1, *b*.) These bacteria have been described as distinct species or varieties under many names. Among them may be mentioned *Bacterium guntheri*, *Bacillus acidi lactici*, and *Streptococcus lacticus*. In spite of the confusion in nomenclature it is evident that the term “lactic-acid bacteria” includes a fairly well-defined group of closely related varieties possessing in common several definite characters. Variations from the type in minor characters produce an almost infinite number of varieties. These variations may be in the ability to ferment different sugars, in the tendency to grow in chains, in the kind of flavor formed in milk, in the intensity of acid formation, and in the ability to produce pathological conditions in animals.

In many creameries the cream is allowed to sour spontaneously. In this case many bacteria other than the true lactic bacteria will take part in the acid formation, and in addition to lactic acid the buttermilk may contain in small quantities acetic, succinic, and formic acids, and sometimes traces of alcohol. The lactic bacteria form lactic acid, with only slight traces of other organic acids, no alcohol, and no gas. In well-managed creameries the acid fermentation is assisted and controlled to some extent by the use of a starter. This may be milk allowed to sour spontaneously, or buttermilk from the previous day's churning, but careful buttermakers build up starters from commercial cultures sold in the form of powders, tablets, or fluid cultures, as varieties of lactic-acid bacteria selected with special reference to the production of a desirable flavor in butter. The buttermaker puts this culture into about a quart of milk which has been steamed for an hour or more to reduce the bacteria to the lowest possible number. After standing overnight the milk will usually be curdled, but gas bubbles and other evidences of contamination may be observed. A small portion of this milk is transferred to another bottle of milk prepared as before, and this process is continued until the acid fermentation has become sufficiently active to eliminate the contaminating bacteria, and the milk curdles with a clean, acid taste and without signs of gas or "wheying off." This small starter, or "mother starter," is carried along indefinitely by daily transfers to freshly steamed milk. If reasonable precautions are taken to prevent contamination after a thorough heating of the milk, this culture will remain pure and vigorous for an indefinite time.

To prepare the starter actually used in ripening the cream, a larger lot of milk—25 to 50 gallons or more, according to the amount of cream—is heated for an hour or more. This is usually done in a special apparatus (sold by creamery supply houses) which consists of a large can inclosed on the sides and bottom by a steam jacket and fitted with a belt-driven stirrer. Milk either skimmed or unskimmed is heated by turning steam into the jacket; during the heating the milk is stirred constantly. After the pasteurization is completed cold water is run into the jacket and the milk cooled to about 24–27° C. (75.2–80.6° F.). A bottle of the mother starter is added and the can is covered and allowed to stand overnight. This gives a large and active pure culture of lactic-acid bacteria to start the acid formation in the cream. Better results are obtained if the cream is first pasteurized.

When lactic-acid bacteria grow in milk the lactose is converted into lactic acid with slight traces of certain other organic acids. This acid breaks up the combination of calcium phosphate and casein which holds the casein in solution, and the casein is precipitated as a firm, jellylike mass. When this occurs in cream the fat globules are en-

tangled in the precipitated casein. In the process of churning the casein is broken into fine particles and the fat globules are collected into large granules that float on the top of the buttermilk. Buttermilk, then, is the water of the milk holding the sugar, acids, ash, and other soluble constituents in solution and the finely divided particles of precipitated casein in suspension. The amount of fat in the buttermilk depends on the completeness with which the fat is removed in the churning. Even with the best methods a little of the fat in the form of very small globules remains in the buttermilk. On standing, the suspended casein settles slowly to the bottom.

The composition of an average buttermilk is about as follows:¹

	Per cent.
Fat-----	0.5
Casein -----	2.4
Albumin -----	.6
Lactose-----	5.3
Ash -----	.7
Total solids-----	9.5

Chemically, buttermilk differs but little from skim milk. Only a slight rearrangement is necessary to bring about the physical change in the casein. If the milk has been pasteurized at a high temperature, the albumin is precipitated and the larger part lost. A small part—less than one-fifth—of the milk sugar is converted into acid. This acid combines with the ash constituents, probably converting the triphosphates into diphosphates and monophosphates and the diphosphates into monophosphates. It is obviously not necessary to make butter in order to secure a perfect substitute for buttermilk. Soured skim milk has all the chemical properties of buttermilk, and if it is thoroughly agitated in order to break up the curd it agrees in appearance and flavor with buttermilk obtained by churning cream.

In making buttermilk from milk the same procedure should be followed as in making a starter for cream ripening. A good, clean-flavored mother starter should be carried along with every possible precaution to prevent contamination. Good commercial cultures can be obtained, but if it is not convenient to use one of these a natural starter should be secured. For this purpose the following procedure may be followed:

(1) Select milk from several sources; put about 1 pint of each into clean glass jars or bottles and allow them to stand in a warm place until the milk is curdled.

(2) When this occurs put about 1 pint of milk into each of an equal number of bottles and hold in steam or boiling water for one-half hour.

¹ Vermont Agricultural Experiment Station. Annual Report, 1891, p. 119.

(3) When these bottles of milk are cooled, transfer about 1 teaspoonful of milk from each of the bottles of sour milk obtained in (1) to one of the bottles of heated and cooled milk.

(4) Allow these samples to curdle and repeat the process until one sample is obtained which curdles in at least 8 or 10 hours with a smooth curd free from whey and gas bubbles and with a pleasant, acid taste.

Gas bubbles, or the separation from the curd of a milky or straw-colored whey, show that the lactic-acid bacteria are still mixed with other kinds. Considerable variation in flavor can be found in different cultures, and care should be exercised to select one that gives a clean and sharp taste.

(5) Propagate this culture in the same way from day to day. The amount of this mother starter which should be carried will depend somewhat on the amount of buttermilk to be made. One quart should be enough for 20 to 30 gallons.

(6) (a) Add the mother starter to the milk to be used for buttermilk, or (b) pasteurize the milk in a continuous pasteurizer at 180° to 185° F. (82° to 85° C.), or preferably hold the milk in water-jacketed vats or cans at 180° F. (82° C.) for 30 minutes to an hour; cool to about 70° F. (21.1° C.) and add the mother starter. The most desirable temperature for this fermentation is 70 to 75° F. (21.1° to 24°C.).

(7) When this milk has curdled, cool it at once to about 50° F. and churn thoroughly to break the curd into fine particles.

The buttermilk should be smooth, free from lumps, and show a separation of whey and curd only on long standing.

Milk to be used for making buttermilk should be fresh and clean flavored. Good buttermilk can not be made from milk that is tainted or too old to be used for other purposes. Skimmed, partly skimmed, or whole milk, as desired, may be used.

A more nearly uniform product is secured if the milk is pasteurized. The scorched taste which results from pasteurization at a high temperature is not objectionable, as it is obscured by the acidity of the soured milk. The time of the inoculation may be arranged to suit the convenience of the maker and can be determined by experience in each individual case. Using the same culture and holding the temperature uniform, the amount of the starter can be adjusted to bring the acidity to the curdling point at any definite time within narrow limits. The temperature of the milk should be between 21° and 24° C. (70° and 75° F.). More rapid development of acid can be obtained at higher temperatures, but at the lower temperatures the lactic-acid bacteria are more successful in checking the growth of digesting and gas-forming bacteria. At lower temperatures and with a slower development of acid the casein is precipitated in a finer and more friable

curd than at temperatures inducing a more rapid acid production. As soon as a fine curd has been formed the milk should be cooled promptly to below 50° F. to prevent the contraction and toughening of the curd.

Buttermilk made in the usual way as a by-product of buttermaking, and especially buttermilk obtained by churning pasteurized cream, is improved by mixing with it about 10 per cent of a skim-milk culture of the *Bacillus bulgaricus*. Directions for the preparation of this culture will be found on page 23.

This culture not only gives the buttermilk a sharper and more agreeable flavor, but on account of its viscous nature it gives it a smoother texture and prevents the separation of the curd from the whey. Detailed directions for the preparation of buttermilk by this method may be found in a circular of the Illinois Agricultural Experiment Station (52).

MAKING BUTTERMILK IN THE HOME.

A more nearly uniform product can be obtained if it is made on a large scale, and if good buttermilk can be purchased from a reliable milk dealer at a reasonable price it is not advisable to attempt to make it on a small scale. However, it is possible to make buttermilk in the home by following in a small way the directions for making buttermilk on a commercial scale. It is necessary first to secure a culture or starter, which is merely milk containing the lactic-acid or sour-milk bacteria free or very nearly free from other kinds. These bacteria are present in any normal milk, and it is only necessary to provide conditions favoring their growth to obtain them in a state of purity.

This may be done by following the directions on page 11 for obtaining cultures for making buttermilk on a large scale. When the culture is obtained it will not be necessary to carry a small culture to inoculate a larger amount.

When the culture is obtained proceed as follows:

(1) Heat 1 quart of milk, which may be skimmed, in a double boiler for at least one-half hour.

(2) Allow the milk to cool to about 75° or 80° F.

At this temperature the outside of the container will feel warm to the hand. Add one teaspoonful of the fresh culture, transfer to a bottle or covered fruit jar, and put away in a warm place. One of the vacuum-jacketed bottles will be found very convenient for this purpose, because the milk can be held at a nearly constant temperature favorable to the growth of the lactic-acid bacteria.

(3) On the following day shake the bottle thoroughly to break up the curd and put the product on ice to cool.

(4) Repeat the process, using a teaspoonful of the freshly curdled milk to inoculate the heated and cooled milk.

Buttermakers in the Northwest make a very refreshing and nutritious drink by adding sugar and lemons to buttermilk. As the casein is already precipitated, the acid juice of the lemon has no effect. Slightly more sugar and lemon juice are necessary than in making ordinary lemonade, and the mixture should be well iced.

KEFIR.

Fermented milks have evidently been extensively used for many centuries by the people of southern Russia, Turkey, the Balkan countries, and their neighbors. The natives have no records and few traditions of the origin of the milks they use, and it is probable that their preparation and use developed gradually by accident and cumulative experience. One of the first of the fermented milks known to Europeans was the kefir, made from the milk of sheep, goats, or cows in the Caucasus Mountains and neighboring regions. Kefir differs from most of the fermented milks of the Mediterranean countries in that it is made from a dried preparation and contains considerable quantities of alcohol and gas. Kefir is made by many tribes under varying names, as "hippe," "kepi," "khapon," "kephir," "kiaphir," and "kaphir," all of which are said to come from a common root signifying a pleasant or agreeable taste.

For a large part of their food the mountaineers of the Caucasus depend on kefir, which they prepare in leather bottles made from the skins of goats. In the summer the skins are hung outdoors, either in the sun or in the shade, according to the weather, but in winter they are kept in the house. The bags are usually hung near a doorway, where they may be frequently shaken or kicked by each passer-by. Fresh milk is added as the kefir is taken out, and the fermentation continues. Made and propagated in this way, foreign bacteria become mingled with the essential bacteria of the grains, and abnormal and frequently disagreeable flavors result. When the milk is drawn off, in order to prevent the escape of gas, a string is first tied around the neck of the leather bottle, so that the small part wanted for use is held between the stricture and the opening. In the villages and the low country kefir is made in open earthen or wooden vessels, and most of the gas escapes.

Small, yellowish, convoluted masses are observed in kefir, which are called seeds or "grains." These grains consist of a central filament of two parts, of which the outer spreads out, forming the convoluted polyp-like exterior. These parts are built up one upon another, giving the large grains a coral-like appearance. The central part is made up of a mass of bacterial threads. In the outer layer

yeast cells are found mingled with the bacteria. When the grains are added to milk they swell and increase in size by forming new grains. At the beginning of the fermentation they settle to the bottom, but in a short time they are carried to the surface by attached bubbles of gas. If the fermentation is active, a thick layer will be formed on the surface, but on shaking or stirring this layer settles again to the bottom.

The biology of kefir was studied by Kern (45) in 1881, but, owing to the faulty technique of that day, his descriptions are evidently erroneous.

Freudenreich (25) describes four organisms that he isolated from kefir grains. One of these was a yeast which he designated *Saccharomyces kefir*; this he found to grow best at 22° C. (72° F.), but not at all at 35° C. (95° F.). It ferments maltose and cane sugar, but not lactose. It gives a peculiar flavor to milk, but causes no fermentation. The cells are oval, 3 to 5 microns by 2 to 3 microns. It is not identical with the ordinary beer yeasts. Two of the organisms were of the lactic-acid bacteria type, but differed from them in forming gas in lactose media. The most interesting of the organisms described is a long, slender bacillus corresponding to one described by Kern as *Dispora caucasica* and to which Freudenreich gave the name *Bacillus causicus*. In morphology, failure to grow on ordinary laboratory media, and in high-acid production in milk, this bacillus resembles very closely the bacillus mentioned later, in connection with yogurt, as *Bacillus bulgaricus*. If Freudenreich's description is accurate, *B. causicus* differs from *B. bulgaricus* by forming gas from lactose and in being feebly motile. Gas was formed slowly at 35° C. and still more slowly at 22° C. (72° F.). No one of these organisms alone produced kefir, but when the four together were grown in milk typical kefir was produced on the first or second transfer.

According to the investigations of Nikolaiewa (64), three organisms are always present in the fermented milk. One of these, *Bacterium causicum*, which forms the filament of the grain, is evidently identical with Freudenreich's *Bacillus causicus*. This investigator considers this bacterium, with a torula yeast fermenting lactose, dextrose, and cane sugar, as essential to the production of kefir. Other bacteria and yeasts are found in the grains and the fermented milk, but they are looked upon as contamination.

It is probable that kefir is produced under different circumstances by different organisms. Any combination of bacteria or of bacteria and yeasts that will produce a lactic-acid and a mild alcoholic fermentation in milk will make kefir, although to secure the most desirable flavor certain organisms may be essential.

Hammarsten (31) shows in the following table the changes brought about in cow's milk by this fermentation:

Chemical analysis of kefir.

	2 days old.	4 days old.	6 days old.
Casein.....	2.570	2.586	2.564
Lactalbumin.....	.425	.405	.390
Peptones.....	.071	.089	.120
Lactose.....	3.700	2.238	1.670
Fat.....	3.619	3.630	3.626
Ash.....	.641	.624	.630
Lactic acid.....	.665	.832	.900
Alcohol.....	.230	.810	1.100

It will be observed that the changes were confined almost entirely to the lactose and its by-products. The casein remained unchanged and the increase in the peptones was insignificant. The lactalbumin decreased slightly. The casein of kefir is, according to this chemist, not especially soluble, but may be more easily digestible because of its finely divided condition. The lactose diminished appreciably, and there was a corresponding augmentation of alcohol and lactic acid. A certain part of the lactose is consumed in the formation of carbon dioxid gas not included in this analysis.

The following directions are given for making kefir when the grains are available: The dry grains are softened by soaking in warm water, which should be changed several times. When the grains rise to the surface and become white and gelatinous they are ready for use. One part of these grains is used to three parts of milk which has been thoroughly heated to destroy the bacteria already present. The bottles in which the milk and grains are placed should not be stoppered but should be protected from the dust by cloths, inverted cups, or plugs of cotton. They are held at a temperature at or near 14° to 16° C. (57° to 60° F.), and stirred or shaken frequently. After eight to ten hours the milk is strained through cloth and put into tightly stopped bottles at the same temperature as before. The bottles should be shaken every few hours to prevent the formation of lumps of precipitated casein. The kefir is ready for use at the end of 24 hours; if held longer than this it is advisable to keep it on ice to check the fermentation. The temperature at which the milk is fermented is important in controlling the relative amounts of alcohol and lactic acid. At higher temperatures the percentage of alcohol is increased, while as the temperature is lowered the alcoholic fermentation diminishes and the quantity of lactic acid formed is greater. After the fermentation is once started the grains may be discarded and new kefir made by adding one part of the fermented milk to three or four of fresh milk. In

order to remove the grains the kefir should be strained through cheese cloth, and after thorough washing to remove the curd the grains may be dried by exposure to the sun on pieces of blotting paper. In this condition they are said to retain their vitality for several years, although many of the yeasts in the outer part of the grain are killed by the desiccation. It may be necessary to break up the grains with the fingers. When in the wet stage they should not be larger than a walnut.

Kefir grains can not ordinarily be obtained in this country, but a good imitation of kefir can be made by carrying on simultaneously in sealed bottles an alcoholic and a lactic fermentation. Better results can be obtained by inducing the alcoholic fermentation in buttermilk. In this way it is possible to avoid much of the trouble from the formation of lumps of curd. If buttermilk is made for this purpose from whole or skimmed milk, careful attention should be given to the time of curdling and the breaking up of the curd. This is essential to a smooth, creamy kefir. Ordinary bread yeast may be used for the alcoholic fermentation, but as this yeast does not ferment lactose it is necessary to add cane sugar to the milk.

(1) Obtain buttermilk from a dealer, or prepare it as directed on page 11.

(2) Prepare the yeast by adding a half teaspoonful of sugar to a 6-ounce or 8-ounce bottle of boiled and cooled water. Add half a yeast cake to this sugar solution and set in a warm place overnight. This will give an active culture of the yeast and obviate the necessity of adding the yeast cake directly to the milk. This yeast culture should be ready at the time the buttermilk is received or, if made at home, at the time it is curdled.

(3) Add 1 to $1\frac{1}{2}$ per cent of sugar to the buttermilk.

On the quantity of sugar added to the buttermilk will depend the extent of the alcoholic fermentation. Theoretically about one-half of the sugar fermented may be converted into alcohol; that is, milk to which 1 per cent of cane sugar has been added may contain after the fermentation one-half of 1 per cent of alcohol. The quantity of sugar added should be governed by the amount of carbon dioxid it is desired to have in the finished product. This should be sufficient to make the kefir distinctly effervescent and impart to it the peculiar, sharp taste of charged water, but should not be developed enough to blow the fluid out of the bottles when the stoppers are removed. Experience shows that 1 to $1\frac{1}{2}$ per cent of sugar will give the right amount of gas. This may be approximated by adding sugar in the proportion of two even teaspoonfuls of sugar to each pint of milk.

Having the buttermilk and the yeast culture ready, dissolve the sugar in the buttermilk.

(4) Add the yeast culture to the buttermilk in the proportion of one teaspoonful to a quart of buttermilk.

(5) Mix thoroughly and bottle. The bottles should be very strong, as sufficient gas pressure is sometimes generated to break ordinary bottles; the heavy bottles used for ginger ale or other carbonated drinks answer this purpose very well. They should be carefully cleaned and boiled or steamed before filling; fill them full and stopper tightly, wiring or tying the stoppers securely in place.

(6) Place in a cool place to ferment.

If the fermentation is too active the kefir will have a yeasty taste and the curd is likely to become lumpy and filled with large gas bubbles. A temperature of 18° C. (65° F.) to 21° C. (70° F.) will be found satisfactory for kefir which is to be used on the third or fourth day. The floor of a cool cellar is a convenient place to ferment kefir made in the home. The bottles should be shaken as often as may be necessary to keep the curd in a finely divided condition. The finished product should be smooth and creamy, effervesce rapidly when poured from the bottle, and have the pleasant, acid taste of buttermilk, with the added sharpness caused by the gas and the trace of alcohol. Kefir 2 or 3 days old may have a yeasty taste, but if it has been properly made this will disappear as the fermentation of the sugar nears completion; made under these conditions it should be used when 3 to 5 days old, but if put on ice it may be held for a week or even longer.

KUMISS.

The missionary monks and other wanderers who first penetrated the undulating, treeless plains of European Russia and central and southwestern Asia brought back descriptions of a fermented drink which in the light of more recent investigations is easily recognized as kumiss. These vast prairies are inhabited by tribes of nomads who live in tents or squalid huts in the winter and wander during the summer, seeking pasture for their horses, their herds of cattle, or flocks of sheep. They are all horsemen, and by a process of selection in which they have probably played only a passive part have developed an exceptionally hardy race of horses. The mares give much more than the ordinary amount of milk, which constitutes almost the entire food of the people during the summer. This is never used in the fresh condition, but is fermented to make kumiss. Unlike kefir, there is no dried "ferment," "seeds," or "grains" with which the fermentation of the mare's milk is started. It is the practice of the natives, when it becomes necessary to establish the fermentation anew, to add to milk some fermenting or decaying matter, such as a piece of flesh, tendon, or vegetable matter. Whatever the material used to supply the essential organisms, it is evident that the milk is so cared

for that a combination of an acid and an alcoholic fermentation is favored and the necessary bacteria and yeast are soon established. No doubt the change in the milk is produced under different circumstances by different combinations of bacteria and yeast, and there are usually present various contaminating organisms which are detrimental or at least are not essential to the production of the kumiss. Native kumiss makers lay great stress on the quality of the milk, the breed of the mares, and the condition of the pastures; but it is probable that their troubles ascribed to variations in these conditions are more likely attributable to imperfectly controlled bacteriological factors.

There was at one time much interest in kumiss as a therapeutic agent in the treatment of tuberculosis, and sanatoria were established in Russia where invalids could get this treatment. It is probable that the benefits, real or imaginary, derived from it came more from the general methods, which correspond somewhat to present practices, than from the action of kumiss.

Mare's milk is lower in nutritive value than cow's milk, as the following table, taken from Richmond's Dairy Chemistry, shows:

Average composition of cow's milk and mare's milk.

	Water.	Fat.	Sugar.	Casein.	Albumin.	Ash.
	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>
Cow.....	87.10	3.90	4.75	3.00	0.40	0.75
Mare.....	90.06	1.09	6.65	1.89		.31

The composition of kumiss varies somewhat with the age, the rapidity of the fermentation, and the nature and extent of contamination with extraneous organisms. The following analysis is taken from Richmond's Dairy Chemistry (p. 241):

Composition of kumiss made from mare's milk.

	1 day old.	8 days old.	22 days old.
	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>
Water.....	91.43	92.12	92.07
Alcohol.....	2.67	2.93	2.98
Lactic acid.....	.77	1.08	1.27
Sugar.....	1.63	.50	.23
Casein.....	.77	.85	.83
Albumin.....	.25	.27	.24
Albumose.....	.98	.76	.77
Fat.....	1.16	1.12	1.30
Ash.....	.35	.35	.35

It will be observed that this fermentation produces no changes that could be expected to increase appreciably the digestibility of the

nitrogenous part of the milk except the possible advantage of a finely divided curd. Mare's milk differs from cow's milk in giving with rennet a softer, more friable curd, but it is not certain that this property would increase the value of kumiss.

Kumiss is often made and offered for sale in this country, but as this is usually made from cow's milk, it is, more correctly, kefir.

YOGURT.

In passing to a consideration of the fermented milks used by the people of the countries bordering on the eastern end of the Mediterranean we find a preparation very distinct from that of the Caucasus and the Russian steppes. Kefir and kumiss are limpid, mildly acid, and distinctly alcoholic; but the yogurt, yahourth, or jugurt of the Turks, the kissélo mléko of the Balkan people, the mazun of Armenia, the gioddù of Sardinia, the dadhi of India, and the leben or leben raib of Egypt, are all thick-curdled milks, decidedly acid, and with very little or no alcohol. The method of preparation is also quite different. Goat's, buffalo's, or cow's milk may be used. This is usually boiled and sometimes is reduced by evaporation to one-half its original volume. In the latter case it is not used as a drink, but is eaten, frequently with the addition of bread, dates, or other food.

A portion of the previously fermented milk is used to ferment the fresh milk. Unlike kefir, there are no "seeds" through which the fermentation can be transmitted, but the essential organism is sometimes preserved by drying the fermented milk and reducing the dry material to a powder. This constitutes the "podkwassa," or "maya." The organism giving these milks their distinctive character is evidently identical in them all, or, more properly speaking, may be any one of the several varieties of a distinct and closely related group. On account of its peculiarities, some of which are exceptional and striking, and the importance recently attached to it by the discussions both in the scientific and the popular press, a brief résumé of its characteristics is given:

This bacterium was probably first observed by Kern (45), who incorrectly designated it *Dispora caucasicum*. His description, however, is so limited that it is impossible to attach the name he proposes to any particular organism. Later Beyerinck (6), under the name *Bacterium caucasicum*, and Freudenreich (25), as *Bacillus caucasicus*, described organisms isolated from kefir which agree in their essential features with those obtained from yogurt. More recently Rist and Khoury (72) isolated from Egyptian leben two bacilli to which they gave the names *Strepto-bacillus lebensis* and *Bacillus lebensis*. Grigoroff (29) and Cohendy (13) isolated similar organisms from Bulgarian fermented milk. These various bacteria are

undoubtedly nearly or quite identical and all are included under the name *Bacillus bulgaricus*, now generally adopted. More strict adherence to the commonly accepted rules of bacteriological nomenclature would retain the name *Bacterium caucasicum* proposed by Beyerinck. Recent work by Hastings (32) and by Heinemann and Hefferan (36) indicates that this bacterium is not peculiar to the eastern fermented milks, but is widely distributed, having been isolated from milk, soil, saliva, feces, and various soured foods. White and Avery (82) believe that this bacterium is the representative of a group of closely related bacteria which they divide into two types on the basis of their activity in milk and the nature of the lactic acid formed. The characteristics of the typical culture may be summarized as follows:

Morphology.—Slender rods 2 microns to 6 or 8 microns in length, breadth usually about 1 micron, flagella and spores absent. Long chains frequently occur and apparently vary with different strains and conditions; pseudobranching has been observed. Very long threads without apparent division are frequently observed in old cultures. Living cells are gram positive; dead cells are gram negative.

Growth on artificial media.—One of the most striking features is its inability to grow on ordinary media. It grows on whey, malt, and slowly on whey agar and certain specially prepared media. The colonies on whey agar are masses of tangled threads resembling colonies of the anthrax bacillus. Gelatin is not liquefied.

Relation to oxygen.—Most varieties grow equally well in the presence or absence of oxygen.

Temperature relations.—The maximum temperature is near 45° C. (113° F.). The minimum growth temperature varies with different members of the group, but it is always comparatively high. Most varieties grow very slowly at 25° C. (77° F.), but some grow at 20° C. (68° F.). Hastings and Hammer (33) state that at 20° C. (68° F.) it forms 4 per cent acid in milk as compared with a maximum of 3 per cent at 37° C. (98° F.). According to White and Avery (82) it is killed by an exposure of 15 minutes at 60° C. (140° F.).

Fermentation of sugars.—Many of the sugars are fermented, but statements of different workers are conflicting. It is probable that this property varies in different varieties.

Milk.—The action of this organism on milk distinguishes it from all other known bacteria. At the optimum temperature milk is curdled in a few hours with a rather soft curd, frequently somewhat slimy, which ordinarily does not separate from the whey even on long standing. In 24 hours the milk may show acidity equivalent to

nearly 2 per cent of lactic acid, and on standing several days this may become about 3 per cent. The most active of the ordinary lactic-acid bacteria seldom exceed 1 per cent lactic acid. The more active type of *Bacterium caucasicum* forms the inactive lactic acid, while the levorotatory acid is produced by the type forming acid more slowly. Small amounts of other organic acids and traces of alcohol are formed.

This bacterium is evidently the *essential* organism of yogurt, matzoon, ceiddu, leben, and similar fermented milks. Other bacteria are always present, some of them habitually and others only occasionally. Some of these may have an influence on the flavor, while others are inert. It is probable that there are none, with the exception of *Bact. caucasicum*, that can not be replaced by other species without appreciably affecting the results. Doubtless slightly different varieties of fermented milk have developed in different localities owing to different combinations of bacteria or of bacteria and yeasts. The Egyptian leben is reported to contain alcohol, but not in quantities sufficient to produce an effervescence such as is observed in kefir or kumiss. One of the ordinary lactic-acid bacteria seems to be always present with the *Bact. caucasicum*, and it is probable that if it is not essential it is of some assistance in starting the lactic fermentation and, especially if the temperature is low, in suppressing contamination before the *Bact. caucasicum* has time to develop sufficient acid to check extraneous bacteria.

Hastings and Hammer (33) could not detect evidences of proteolytic enzymes by the usual tests, but found in old-milk cultures a distinct peptonization of the casein which was not traceable to the action of the acid. This change is so slow and so small that it can not be considered as having any influence on the digestibility of the milk. Otherwise the only changes in the milk constituents are in the conversion of the sugar to lactic acid and very small amounts of volatile acids and traces of alcohol.

"Yogurt buttermilk" is now sold in several cities, and the growing demand will doubtless soon extend its manufacture more generally. In making yogurt in this country better results are obtained by using with the *Bact. caucasicum* a culture of an ordinary lactic-acid organism such as is used in making buttermilk. *Bact. caucasicum* growing alone in milk forms usually a rather slimy, tenacious curd which can not be broken up into the smooth, creamy condition essential to a good buttermilk. If this organism is grown in combination with the ordinary lactic-acid organism, a more friable curd is obtained, and the sliminess is not so evident. The two organisms can be carried in mixed culture only with great difficulty, as the high acid soon suppresses the ordinary form. The most satisfactory results can be ob-

tained by making buttermilk in the ordinary way and churning it with an equal quantity of milk curdled with the yogurt organism. This procedure gives the desirable texture of buttermilk and a distinctive flavor.

If a culture can be obtained, yogurt can be made in the home. If a reasonably active dry or fluid culture can be obtained, the following procedure should be satisfactory:

(1) Heat one-half pint of milk in a double boiler, holding it one-half hour after the water begins to boil.

(2) Cool this milk to about 100° F. (about blood heat). At this temperature the container will feel warm, but not hot, to the touch.

(3) Add a considerable quantity of the culture to this milk. If it is in the form of tablets three or four should be used.

(4) Transfer the milk to a bottle or fruit jar—or, better still, a vacuum-insulated bottle—which has been rinsed with boiling water, and hold overnight in a warm place. Good results may be obtained by placing the bottle or jar, containing the milk, in a dish of water warmed to about 100° F. The most favorable temperature for the fermentation is at or a little below blood heat. At a little higher temperature the organism grows faster, but the curd is likely to separate from the whey as a tough mass. At a lower temperature the growth may be so slow that other bacteria gain the ascendancy. By the following morning the milk should be curdled with a thick, somewhat stringy curd with a sharp, acid taste.

(5) Heat 1 pint to 1 quart of milk as in (1), cool and add 1 teaspoonful of the curdled milk obtained in (4).

Hold this milk as before, and when it has curdled break up the curd by shaking vigorously in a fruit jar.

This process may be repeated so long as the curdled milk has a smooth, acid curd free from undesirable flavors and particularly the yeasty flavor and odor characteristic of bread dough. The so-called *Bacillus bulgaricus*, under favorable circumstances, will suppress other bacteria by its vigorous acid formation, but yeasts are favored by the acid condition of the milk and sooner or later make their appearance. Every precaution should be taken to protect the milk from exposure to the air and to sterilize all utensils with boiling water. When evidences of yeast contamination appear it is best to start with a fresh culture.

Yogurt may be made more palatable by adding to two parts of the yogurt one part of cold water, or, better still, cold-charged water, which can be bought in siphons at drug stores. Sugar and lemon juice or other fruit flavor, or chocolate sirup may also be used for this purpose. The sugar should be added in the form of a sirup, as granulated sugar dissolves very slowly in the cold yogurt.

In making yogurt on a large scale the process is not essentially different except that it is advisable to carry a small culture, about 1 quart, to inoculate the milk to be made into buttermilk. Every precaution should be taken to maintain the purity of the culture. It is advisable to carry duplicate cultures independently so that a good one will always be available.

Expensive outfits for making fermented milks are on the market, but while they may be convenient they are by no means essential. For the smaller dairy the following procedure will probably be found satisfactory:

(1) Propagate a small culture from day to day as indicated in the directions given above.

(2) Carry in a similar way a culture of the ordinary sour-milk organism, which may be obtained from many of the commercial laboratories.

(3) Thoroughly pasteurize the milk to be fermented. If a small quantity—5 to 10 gallons, for instance—is to be made, it may be done by holding a can of milk in a tub or vat of water heated by a steam hose. If a larger quantity is made, one of the starter cans used in creameries will be found convenient. These are essentially cylindrical vats with mechanical stirrers and a jacket which can be filled with steam for heating or water for cooling. The milk should be held at a temperature of at least 180° F. for not less than 30 minutes.

(4) Cool the milk to about 100° F. Draw off one-half and inoculate it with the culture obtained in (2). Inoculate the remaining half with the bulgaricus culture obtained in (1). The amount to be added will depend on the quantity of milk to be fermented, the time at which it is desired to have it curdled, and the temperature maintained during the fermentation. This can best be determined by experience. One pint should be sufficient for any amount between 10 and 20 gallons.

(5) The milk inoculated with (2) may be held at ordinary room temperature. Precautions must be taken to hold that part inoculated with the bulgaricus culture at a temperature of 90° to 100° F. for several hours. If the milk is in cans it may be set in a tub of warm water. A large volume of milk in a warm room will maintain the proper temperature.

If one is unable to hold the milk at the desired temperature, the amount of culture inoculation should be increased.

(6) When the milk has curdled, which should be in 10 or 12 hours, mix the two lots thoroughly by churning or stirring together, bottle, and put on ice to check the acid formation.

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FARM PRACTICE IN THE CULTIVATION OF CORN.

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INTRODUCTION.

The subject of tillage is one upon which much fundamental information is yet to be supplied. Numerous tillage experiments have been conducted by various agricultural experiment stations, but a compilation of the results of these experiments shows that no general conclusions can be drawn from them; in fact, the results in different States seriously conflict. This is probably due to the fact that the experiments have been conducted upon different types of soil and under other widely varying conditions, as well as to the fact that in many cases experiments have not been repeated a sufficient number of times to justify conclusions, even locally. Further, the experiments have usually been designed to find out the most productive practices, whereas the farmer is interested in the most profitable practice.

Previous studies, reported in Bulletin 257 of the Bureau of Plant Industry,² have shown that the principal object of intertillage in

¹ The Office of Farm Management was transferred from the Bureau of Plant Industry to the Office of the Secretary on July 1, 1915. The work upon which this paper is based was done and the manuscript was submitted and its publication arranged before the transfer took place.

² Cates, J. S., and Cox, H. R. The weed factor in the cultivation of corn. U. S. Dept. Agr., Bur. Plant Indus. Bul. 257, 35 p., 10 fig. 1912.

NOTE.—This bulletin gives the results of an extensive study of cultural practice with corn and should be of interest to farmers in all regions where corn is grown.

growing a crop of corn is the elimination of weeds, but these studies gave no information as to the reason for the great variation in tillage practices prevailing in the different sections of the country. It was quite natural, therefore, that the work originally undertaken should lead to a study of these variations in local practices, with a view to ascertaining the fundamental causes of existing differences, and of determining whether these differences were due merely to difference in the weeds which must be combated or to difference in economic conditions in the various agricultural sections of the country.

The fact that the local practice in the preparation of the seed bed for corn varies as widely as do the local practices with reference to intertillage itself suggested that the differences in methods of intertillage were due not merely to differences in the weed population. It was therefore decided to extend the study so as to include local practices in the various agricultural regions having to do with the preparation of the seed bed, as well as the intertillage of the corn crop. It was recognized that on the average the farmers in the different agricultural areas had worked out methods of tillage which were at least fairly satisfactory under their conditions, and it was therefore believed that a study of these various methods which have proved profitable through long experience in various localities, and studies of the conditions under which they prevailed, might lead to the discovery of the factors which control differences in local practice. As will be seen in the following pages, this expectation was fully realized.

These studies were made in selected regions (fig. 1) which include in a general way all important corn-growing sections of the country. In selecting these regions it was the aim to choose those having conditions and methods which are representative of large areas. The studies herein set forth, therefore, give the reader a broad, general idea of the tillage methods actually employed in corn growing. Incidentally, the yields related thereto are also given.

In all, 21 regions were covered. About 25 representative farms were studied in each region. A record was taken from each farmer visited, showing in detail his tillage practices with corn and also the general practices and conditions on his farm. The detailed results of these studies are presented in tabular form. The general information is first presented and then the tillage data.

The records for each region were tabulated and the averages as presented in Tables I and II will give the reader a good general idea of farming conditions in the regions under discussion. Other tables are presented which relate to plowing, planting, subsoiling, and miscellaneous tillage operations.

A table relating entirely to tillage is given for each section. This table shows in detail the tillage operations for corn after plowing

and before planting, and also gives in detail the tillage operations after planting. In addition to these tables a description is given of each section studied, discussing the general conditions and customs found there.

It is not improbable that tillage methods found in some sections of the country could, to a greater or less extent, be profitably employed in other sections. In this publication, however, we are concerned merely with setting forth the findings on actual tillage methods employed by representative corn growers in the areas studied, and no attempt has been made to make recommendations based on the results of these studies.

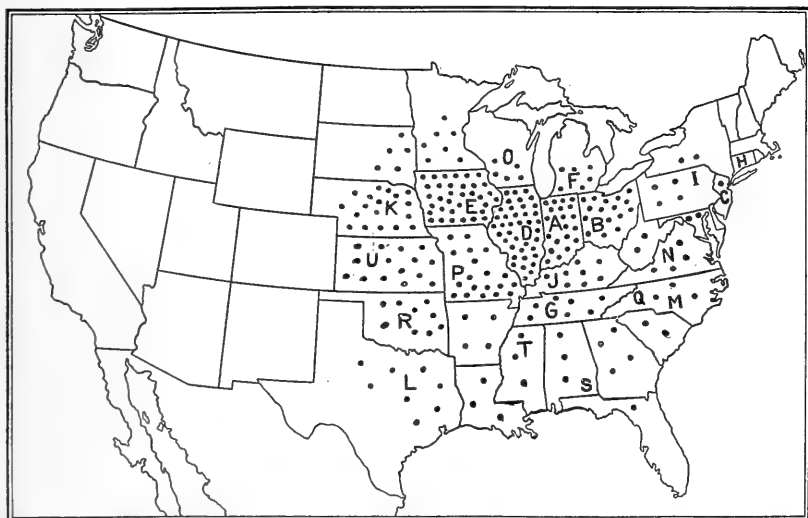


FIG. 1.—Outline map of the United States, showing the distribution of corn production by States, each small black dot representing a yield of 10,000,000 bushels (census of 1910). The counties and States in which the regional corn-tillage surveys were made are indicated by key letters showing locations, as follows: A=Tipton, Ind.; B=Montgomery, Ohio; C=Mercer, N. J.; D=Moultrie, Ill.; E=Tama, Iowa; F=Kalamazoo, Mich.; G=Maury, Tenn.; H=Hartford, Conn.; I=Bradford, Pa.; J=Christian, Ky.; K=Hamilton, Nebr.; L=Rockwall and Grayson, Tex.; M=Scotland, N. C.; N=Augusta, Va.; O=Waushara, Wis.; P=Bates, Mo.; Q=Alexander, N. C.; R=Oklahoma, Okla.; S=Pike, Ala.; T=Holmes, Miss.; U=Russell, Kans.

The illustrations in this bulletin are given simply as types of machines and are not designed to show any particular make. There are many machines on the market which may be utilized with perfectly satisfactory results for the various farm operations illustrated and described.

GENERAL STATEMENT.

The subject of tillage of corn can properly be divided into two parts. The first has to do with the preparation of the seed bed, and the second with the cultivation of the growing crop. Both in the preparation of the seed bed and in intertillage the prevailing con-

ditions with reference to farm labor and farm capital are the principal factors in determining differences in practice. In the preparation of the seed bed the soil type is also an important factor, while in intertillage the types of weeds to be dealt with have much to do with prevailing practices. The reason why greater variation in results is not shown for the different methods and amounts of intertillage is that, in the main, all the practices studied were adequate for weed control in the growing crop in the regions where these practices are employed. (Table I.)

Previous investigations have shown that if weeds are eliminated, any sort of intertillage becomes of minor consideration.¹ The whole subject, therefore, is far more largely of economic than of agronomic importance. What the farmer wants to know concerning seed-bed preparation is: What is the cheapest method of making an adequate seed bed under his conditions? An adequate seed bed may be defined as land free from weeds and surface trash, sufficiently mellow to permit easy penetration of the plant roots, sufficiently compact to hold moisture and to be free from large air spaces, and sufficiently fine in texture to bring many soil particles in contact with the seed and thus to supply an abundance of moisture to the germinating plant. Land so prepared is also in good condition for subsequent tillage. What he wants to know concerning intertillage is: What is the cheapest method of controlling weeds which infest his growing crops?

TABLE I.—*Summary of tillage practices with corn, showing the averages of depth of plowing, number of cultivations, price of land, commercial fertilizer used, and normal yields per acre in twenty-one regions of the United States.*

Region covered (fig. 1).		Depth of plowing.	Workings after plowing and before planting.	Cultivations after planting.	Price of land per acre.	Commercial fertilizer used.		Normal yield.
Key letter.	County and State.					Farms applying.	Applied per acre.	
		Inches.				Per cent.	Pounds.	Bushels.
A	Tipton, Ind.	6.7	2.8	5.5	\$209.48	3.4	200.0	57.4
B	Montgomery, Ohio.	7.1	3.6	4.0	146.96	31.0	217.2	52.3
C	Mercer, N. J.	6.3	3.5	5.9	101.87	78.1	331.7	51.1
D	Moultrie, Ill.	5.4	3.2	4.4	198.30	0	.....	49.5
E	Tama, Iowa.	5.1	3.0	5.3	196.40	0	.....	46.6
F	Kalamazoo, Mich.	6.7	3.3	5.0	101.40	0	.....	41.5
G	Maury, Tenn.	7.7	2.7	5.4	110.38	0	.....	40.9
H	Hartford, Conn.	7.4	2.4	3.8	138.80	88.0	727.3	39.9
I	Bradford, Pa.	6.1	2.5	4.4	51.20	28.6	178.1	38.2
J	Christian, Ky.	7.1	3.0	5.1	69.04	3.8	125.0	36.9
K	Hamilton, Nebr.	5.8	2.5	5.1	158.38	0	.....	35.0
L	Rockwall and Grayson, Tex.	6.4	1.5	3.9	103.41	0	.....	33.6
M	Scotland, N. C.	7.0	2.3	4.3	113.50	100	575.7	35.0
N	Augusta, Va.	8.0	3.0	4.1	71.80	42.9	161.3	33.0
O	Wausara, Wis.	5.5	1.8	5.4	48.27	0	.....	30.4
P	Bates, Mo.	5.9	2.3	4.8	95.00	0	.....	29.3
Q	Alexander, N. C.	6.0	1.1	5.1	39.14	78.9	123.1	25.2
R	Oklahoma, Okla.	5.6	1.5	3.9	50.00	0	.....	23.9
S	Pike, Ala.	6.7	.6	4.7	36.50	90.5	366.8	23.1
T	Holmes, Miss.	5.1	1.4	4.7	22.40	4.0	200.0	22.0
U	Russell, Kans.	5.5	0	3.8	43.20	0	.....	20.4

¹ See Bureau of Plant Industry Bulletin No. 257, already mentioned.

For the reasons above stated this bulletin should not be expected to embody a so-called best method of conducting tillage operations everywhere applicable to corn growing. Such detailed information as is here presented amounts, as it were, to taking the reader on a tour of study to visit not only his neighboring corn-raising farmers, but representative corn growers in all the important corn-producing regions of the United States. On such a trip one would expect to get ideas and suggestions to be brought home and tried out. It would be unsafe to recommend for general adoption in any corn-growing region practices which have never been tested there, however successful such practices may have proved in other sections, but in many cases it would be highly desirable for a farmer to try methods which have elsewhere proved successful. These studies, then, should be of great suggestive value to both experimenters and practical farmers.

GROUPS OF CORN-GROWING AREAS.

The regions in which surveys were made may be grouped into five divisions, as follows: (1) The central western, (2) the southeastern, (3) the south central, (4) the southwestern, and (5) the northeastern. In each of these divisions more or less distinct methods and practices are employed.

The first division includes the corn belt proper. Here the tillage practices are very uniform. The land is level or gently rolling. Heavy teams are employed for breaking and preparing the land; gang plows, 2-horse checkrow planters, and 2-horse 6-shovel cultivators are generally used. Corn is usually planted level and in checks.

In the southeastern division, including in the main the cotton belt, a radically different type of tillage is practiced. Here mostly 1-horse implements are employed. Corn is usually planted in the water furrow between beds or in rows laid off with a lister, or middle buster. In cultivating, 1-horse turning plows, cotton sweeps, and 1-horse cultivators are largely employed. The furrow in which the corn is planted is gradually filled up by cultivating until the field is practically level at the last cultivation.

The south-central division, composed of Tennessee, Kentucky, and western North Carolina, is located between the corn and cotton belts and has tillage methods which combine practices from both regions. Here little uniformity is found.

The southwestern division, which includes northern Texas, Oklahoma, and western Kansas, constitutes a comparatively new agricultural region with tillage methods peculiar to that section. Most of the corn is listed, as is the case in all the Southern States, but here heavy teams are employed. The land is bedded with 3-horse or 4-horse listers, accomplishing the same result with one furrow as the

1-horse plows of the South Atlantic States do with four or six furrows. A combined lister and planter is often used, which breaks the land and plants the corn all at one operation. Where this implement is used, often no other preparation is given the land before the corn is planted.

In the northeastern division corn is a minor crop and the tillage methods employed are those which are best suited to the principal crops grown in the region. In the New Jersey area the principal crop is potatoes, and in this region corn is cultivated with the same implements which are used for the potato crop. In Connecticut, where tobacco is the leading crop, the tillage methods for corn are those best suited for cultivating tobacco.

TILLAGE GENERALIZATIONS.

Subsoiling is not extensively practiced and is usually employed only in regions having soils low in organic matter.

The depth of breaking land is governed largely by the type of soil and time of plowing. Sandy or loamy soils, unless underlain with a stiff subsoil, are usually plowed deeper than the heavy clay soils. When land is plowed in the fall it is usually broken deeper than when plowed in the spring.

Listing is extensively practiced in those regions where hot, dry weather prevails during the growing season.

Whether corn is planted in checks or drills depends largely on the extent to which corn is grown, on the size and shape of the fields, and on the topography of the land. Where the land is level and corn is extensively grown it is usually planted in checks, unless listing is practiced. Where corn is not extensively grown and where consequently the fields are small, or where the land is rolling, drill planting is practiced.

The thickness of planting corn varies with the fertility of the soil. It is planted thickest on the most productive soils.

On the most productive farms slightly more cultivation is given corn, both before and after planting, than on the less fertile soils. With tillage after plowing and before planting, the increased work for the higher yielding regions is significant. For instance, for the 10 best regions (Table II) the average number of cultivations after plowing and before planting is 3, while for the 10 poorest regions the average is only 1.6. This, however, may be due to the fact that the character of the heavy clay soils of the Central West, the region where high normal yields most often occur, is such as to require more preparation than the lighter soils of other regions. Further, it may be that with the more fertile soils the increased yield in response to extra good preparation fully warrants such expenditure of labor. With the inherently poorer soils this may not be the case. To illustrate this point, we might assume that a certain percentage

of increase is caused in all cases by this extra preparation. Suppose we place this increase at 10 per cent. Soils yielding normally 60 bushels per acre would then be increased 6 bushels by such extra work. With soils, however, having a normal yield of only 20 bushels per acre the increase for the same amount of work would be but 2 bushels. This latter amount might be too small to warrant such practice.

TABLE II.—*Corn culture in the United States, showing farm practice averages summarized by divisions.*

Regions covered (fig. 1).	Area of farms.		Per acre.		Fall plow- ing.		Spring plow- ing.		Fall and spring plowing.		
	Total.	Culti- vated.	Price of land.	Normal yield.	Farm- ers prac- tic- ing.	Depth.	Farm- ers prac- tic- ing.	Depth.	Farm- ers prac- tic- ing.	Depth.	
										Fall.	Spring.
Ten regions:	<i>Acres.</i>	<i>Acres.</i>		<i>Bushels.</i>	<i>P. ct.</i>	<i>In.</i>	<i>P. ct.</i>	<i>In.</i>	<i>P. ct.</i>	<i>In.</i>	<i>In.</i>
Best.....	189.1	154.4	\$132.38	45.4	24.0	6.6	73.8	6.4	2.1	8.2	6.0
Poorest.....	294.6	179.4	62.32	27.4	17.2	7.0	72.6	5.7	10.2	7.8	4.8
Average of all.....	242.7	170.3	100.25	36.3	20.0	6.8	74.1	6.0	5.9	7.9	5.1
Divisions:											
Central western.....	176.4	150.6	167.42	45.0	21.1	6.1	78.9	5.9	0	0	0
Northeastern.....	104.2	80.1	97.29	43.1	19.2	6.6	80.8	6.5	0	0	0
South central.....	343.0	248.7	72.85	34.3	35.9	7.0	45.2	6.7	18.9	8.1	5.3
Southwestern.....	380.5	231.9	65.54	26.0	12.4	5.9	71.5	5.3	16.1	6.5	5.9
Southeastern.....	334.7	194.6	57.46	26.0	2.9	9.0	91.1	5.4	6.0	8.7	4.3

Regions covered (fig. 1).	Cultivations given.		Area per horse.		Farmers practic- ing hand labor.	Cost of labor.	
	After plowing and before planting.	After planting.	Culti- vated land.	Inter- tilled crop.		Per day.	Per month.
Ten regions:			<i>Acres.</i>	<i>Acres.</i>	<i>Per cent.</i>		
Best.....	3	4.9	24.4	6.6	39.8	\$1.39	\$24.14
Poorest.....	1.6	4.5	28.4	14.5	56.9	1.09	21.45
Average of all.....	2.3	4.6	26.4	10.5	46.4	1.25	23.55
Divisions:							
Central western.....	2.9	4.8	21.6	7.9	28.8	1.53	27.49
Northeastern.....	2.8	4.7	21.0	5.0	71.4	1.49	25.04
South central.....	2.3	5.2	35.9	9.0	41.6	.76	17.69
Southwestern.....	1.0	3.9	27.7	15.7	43.4	1.38	25.00
Southeastern.....	1.4	4.6	26.9	21.7	73.2	.71	12.41

It is shown in Table II that in the regions making the highest yield of corn the least handwork is done. It is not thought, however, that there is any relation between the amount of hand labor and the yield of corn. Where the topography of a region is level and corn is grown in large acreages in a field, it is usually planted in checks and cultivated in alternate directions. Where this is done, very little hand labor is employed. Where the fields are small or where the land is rolling, checkrowing is not as a rule practiced. In this case hand labor is more extensively employed. Hand labor, therefore, compared with yield must be considered merely as an associated rather than a related factor.

YIELD FACTORS OTHER THAN TILLAGE.

In such a study as this it is impossible to measure the effect of tillage in terms of yield. This is true, for the reason that tillage is only one of the many factors which have to do with yield, and while yields are, for the most part, given in connection with these studies, it is firmly believed that the yields are far more closely related to the inherent fertility of the soil and to the general farm practices than to tillage.

The variations in yields, both regional and on individual farms in a given region, show but scant correlation to variations in tillage practice. There is, however, a striking correlation between yields and type of farming. Yields in the main in the different regions are in inverse ratio to the area of improved land which is in intertilled crops. In some of the regions surveyed other factors enter which affect crop yields, and in those regions this relation between the yield of corn and the area of intertilled crops does not exist. Such conditions are found in Scotland County, N. C., and Hartford County, Conn., where large quantities of commercial fertilizer are used, and in Augusta County, Va., and Bradford County, Pa., where the land is rolling or rough and corn is grown mostly on the bottom lands with hay and pasture on the hillsides. However, notwithstanding these factors, when the regions included in this study are arranged in order of rank in yield, the first 10 show but 29.5 per cent of improved land in intertilled crops, with a yield of 45.4 bushels of corn per acre, while the remainder show an average of 52 per cent of the improved land intertilled, with a yield of only 27.4 bushels of corn per acre. Again, it is well known that in a large measure hay and pasture enter into the rotation to supplement intertilled crops. In other words, far more than for tillage, yields of corn tend to vary directly with the extent to which crops adding organic matter to the soil—hay and pasture crops—enter into the rotation.

ECONOMIC FACTORS INFLUENCING TILLAGE.

In Table I, as in all the general tables, the areas surveyed are placed in the order of bushel yield of corn per acre, starting with the area having the highest yield. The only direct bearing of Tables II and III on tillage is in showing the acreage of cultivated land and of intertilled crops per horse for the regions studied. The other matter presented, however, does have an important indirect bearing on the subject of tillage, in that it gives the reader a general knowledge of existing farm conditions. This information is necessary to a proper interpretation of the purely tillage data presented in subsequent tables.

Table III shows that in the regions where land is less expensive and labor cheap the farms are large, with a small percentage of the land under cultivation. Where land is more expensive the farms are smaller, with a larger percentage of it under cultivation. Of the regions surveyed, the 10 having the highest priced land have an average farm size of 201 acres, with 80 per cent of the farm land tillable. For the 10 regions having the lowest priced land, the average farm size is 291 acres, with only 63 per cent of the farm land tillable.

TABLE III.—*Number of farm projects surveyed, area in farms, average acreage per head of live stock, and average cost of farm labor in twenty-one regions of the United States.*

Region covered (fig. 1).		Date of survey.	Records taken.	Average land per farm.			Average cultivated land per head.		Average land per horse.		Average price of farm labor.	
Key letter.	County and State.			Total.	Cultivated.	Value per acre.	Cattle.	Hogs.	Cultivated.	Intertilled crops.	Per day.	Per month.
				<i>Acres.</i>	<i>Acres.</i>		<i>Acres.</i>	<i>Acres.</i>	<i>Acres.</i>	<i>Acres.</i>		
A	Tipton, Ind.....	July, 1913	29	184.6	153.0	\$209.48	7.8	2.2	21.9	7.4	\$1.21	\$24.90
B	Montgomery, Ohio	do.....	29	86.5	76.3	146.96	9.8	2.4	17.9	6.2	1.42	19.00
C	Mercer, N. J.....	Aug., 1913	32	109.6	93.8	101.87	10.3	21.5	17.0	6.9	1.50	26.46
D	Moultrie, Ill.....	Oct., 1912	59	192.9	177.6	198.30	24.7	11.3	18.4	8.8	1.18	28.67
E	Tama, Iowa.....	Aug., 1914	25	148.8	109.7	196.40	4.6	1.6	18.8	7.5	2.00	33.68
F	Kalamazoo, Mich.	Oct., 1913	26	172.8	138.9	101.40	20.3	4.3	28.6	5.7	1.50	24.67
G	Maurv, Tenn.....	Nov., 1913	15	389.0	303.3	110.38	7.1	7.6	40.3	7.2	.75	17.95
H	Hartford, Conn...	Oct., 1913	25	93.5	62.7	138.80	4.6	2.2	17.8	5.4	1.68	26.67
I	Bradford, Pa.....	Sept., 1913	28	109.4	83.7	51.20	6.3	16.8	28.3	2.6	1.30	22.00
J	Christian, Ky.....	Nov., 1913	26	404.0	345.0	69.04	29.2	7.0	34.9	8.5	.....	17.43
K	Hamilton, Nebr....	June, 1913	25	261.0	240.0	158.38	13.3	3.1	27.4	9.6	1.94	34.44
L	Rockwalland Grayson, Tex.	Apr., 1913	24	271.6	230.4	103.41	41.3	25.0	30.9	17.6	1.12	25.00
M	Scotland, N. C....	Nov., 1912	38	274.1	170.8	113.50	37.6	14.4	24.7	19.3	.75	.....
N	Augusta, Va.....	Sept., 1913	28	209.4	142.6	71.80	9.2	14.2	33.8	4.7	1.08	16.40
O	Waushara, Wis....	June, 1913	26	170.4	126.8	48.27	14.0	14.4	30.8	8.9	1.34	31.11
P	Bates, Mo.....	Aug., 1914	25	184.8	146.8	95.00	8.1	3.1	23.3	8.0	1.45	24.25
Q	Alexander, N. C....	Nov. 1913	14	236.0	97.8	39.14	14.6	13.8	32.6	11.2	.77	.....
R	Oklahoma, Okla...	May, 1913	21	214.9	134.3	50.00	13.3	4.8	23.1	15.0	1.12	22.92
S	Pike, Ala.....	Mar., 1913	21	328.4	198.0	36.50	20.8	5.8	31.3	24.2	.71	14.13
T	Holmes, Miss.....	Apr., 1913	25	401.8	215.0	22.40	11.7	18.9	24.7	21.7	.69	10.69
U	Russell, Kans.....	Aug., 1914	25	655.0	331.0	43.20	7.0	7.7	29.0	14.5	1.90	27.10

The number of cattle and hogs found in a region is undoubtedly governed by the available pastures and the price of feeds. Where good pastures abound and where grain and hay can be produced cheaply more cattle and hogs are found.

Less acreage is worked per horse in the regions where improved implements and heavy teams are employed than in the regions where small teams and 1-horse implements predominate. This is probably due partly to the fact that in the Central West, where a small acreage is worked per horse, many colts are raised, and extra mares are kept on the farm for this purpose. The fact that larger yields of crops are made and more live stock kept on the farms in the Middle West where these heavy horses and implements are used makes also for a

greatly increased amount of work other than tillage. Labor, however, is more efficient and a greater acreage is cultivated per man where more horses and better equipment are used. The quality of labor available, the type of farming, and the topography of the land largely regulate the size of teams to be used. With very cheap labor, 1-horse implements may be more economical than heavier implements, since slightly more land is worked with two 1-horse teams than with one 2-horse team.

The cost of labor given is the average of what the farmers interviewed actually pay. Where cheap labor is available crops which require much hand labor predominate.

ACREAGE AND CROP YIELDS.

Table IV gives the reader a general idea of the types of farming practiced in each region surveyed. The normal acreages and normal crop yields, as shown, represent the averages for the farms visited in each region.

TABLE IV.—*Normal average acreage per farm and yield per acre of various crops on the farms surveyed in twenty-one regions of the United States.*

Region covered (fig. 1).		Corn.		Oats.		Wheat.		Hay.	
Key letter.	County and State.	Per farm.	Yield per acre.	Per farm.	Yield per acre.	Per farm.	Yield per acre.	Per farm.	Yield per acre.
		<i>Acres.</i>	<i>Bushels.</i>	<i>Acres.</i>	<i>Bushels.</i>	<i>Acres.</i>	<i>Bushels.</i>	<i>Acres.</i>	<i>Tons.</i>
A	Tipton, Ind.	52.1	57.4	24.1	51.0	19.6	21.4	35.3	1.89
B	Montgomery, Ohio	20.4	52.3	6.1	40.4	17.5	21.8	16.8	1.67
C	Mercer, N. J.	18.0	51.1			7.1	24.2	24.0	1.79
D	Moultrie, Ill.	83.5	49.3	28.7	41.2	6.2	21.2	13.5	1.75
E	Tama, Iowa	44.0	46.6	26.6	35.5		20.0	21.5	1.50
F	Kalamazoo, Mich.	27.6	41.5	19.9	37.2	39.4	19.8	24.0	1.45
G	Maury, Tenn.	54.4	40.9	26.1	31.7	72.0	18.5	47.0	1.57
H	Hartford, Conn.	9.3	39.9	1.4	30.0			21.0	1.72
I	Bradford, Pa.	7.8	38.2	9.1	30.0	2.5	20.6	25.0	1.70
J	Christian, Ky.	55.4	36.9	25.0	30.0	111.6	16.8	77.9	1.08
K	Hamilton, Nebr.	83.8	35.0	19.0	28.7	77.0	23.5	a 26.2	a 3.50
L	Rockwall and Grayson, Tex.	40.8	33.6	49.7	45.6	41.7	18.9		
M	Scotland, N. C.	40.0	33.0	3.0	49.7			5.3	1.10
N	Augusta, Va.	20.0	33.0			37.1	16.0	30.1	1.01
O	Waukhara, Wis.	18.3	30.4	16.4	22.4			17.7	1.04
P	Bates, Mo.	49.0	29.3	21.4	29.0	24.9	19.0	31.9	1.00
Q	Alexander, N. C.	25.3	25.2	7.0	10.5	19.1	11.0		
R	Oklahoma, Okla.	47.2	23.9	16.7	31.5	9.9	16.6	a 17.3	a 3.67
S	Pike, Ala.	56.0	23.1	10.0	35.7				
T	Holmes, Miss.	112.5	22.0	4.0	25.0				
U	Russell, Kans.	125.0	20.4			185.0	17.5	a 10.0	a 2.00

a Alfalfa.

TABLE IV.—*Normal average acreage per farm and yield per acre of various crops on the farms surveyed in twenty-one regions of the United States—Contd.*

Region covered (fig. 1).		Cotton.		Rye.		Potatoes.		Tobacco.		Pasture and all other crops.
Key letter.	County and State.	Per farm.	Yield per acre.	Per farm.	Yield per acre.	Per farm.	Yield per acre.	Per farm.	Yield per acre.	Per farm.
		<i>Acres.</i>	<i>Pounds.</i>	<i>Acres.</i>	<i>Bushels.</i>	<i>Acres.</i>	<i>Bushels.</i>	<i>Acres.</i>	<i>Pounds.</i>	<i>Acres.</i>
A	Tipton, Ind.									21.9
B	Montgomery, Ohio							6.0	1,004.8	9.5
C	Mercer, N. J.			13.1	20.6	17.5	147.8			14.1
D	Moultrie, Ill.									45.7
E	Tama, Iowa									17.6
F	Kalamazoo, Mich.									28.0
G	Maury, Tenn.			3.3	13.2					100.5
H	Hartford, Conn.			1.0	18.3	1.4	151.9	8.3	1,799.0	20.3
I	Bradford, Pa.			3.2	16.5					36.1
J	Christian, Ky.							27.3	936.0	47.9
K	Hamilton, Nebr.									34.0
L	Rockwall and Grayson, Tex.	90.7	720.0							7.5
M	Scotland, N. C.	98.6	1,328.0							23.9
N	Augusta, Va.									55.4
O	Waushara, Wis.			30.3	12.3	18.2	110.4			25.9
P	Bates, Mo.									19.6
Q	Alexander, N. C.	8.5	794.2	8.1	8.6					29.8
R	Oklahoma, Okla.	12.5	580.5							30.7
S	Pike, Ala.	94.8	862.5							37.2
T	Holmes, Miss.	75.2	704.8							23.3
U	Russell, Kans.									11.0

SUBSOILING, DRAINAGE, AND TILLAGE BEFORE PLOWING.

Subsoiling is the process of breaking up or loosening the subsoil without mixing it with the topsoil. This is usually done by plowing a furrow with an ordinary turning plow (fig. 2) and following in the bottom of this furrow with a shovel or bull-tongue plow, which loosens the subsoil but does not bring it nearer the surface or mix it with the topsoil. In some sections partial subsoiling is practiced by running a subsoil plow in the bottom of the corn row before planting the corn, as is the practice in Scotland County, N. C., and Pike County, Ala. The results of subsoiling presented in Table V clearly show that this practice is not extensive and is usually carried on only in regions which have soils low in organic matter.

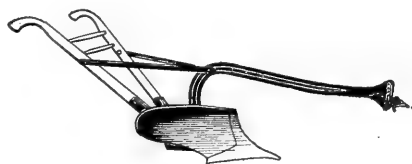


FIG. 2.—A 2-horse turning plow, a type of implement used throughout the corn-growing States.

The amount of data available in regard to subsoiling is so limited that no definite conclusions can be drawn. Table V presents a digest of the opinions of farmers concerning the effect of subsoiling on the crop yield, showing the percentage of those who have practiced it, the season when it is usually done, and the average depth. Opinions were recorded from some farmers who had not practiced subsoiling.

It is interesting to note that these opinions vary with the different kinds of soil. Where there is a sandy or loamy soil underlain with a heavy clay subsoil, as in Maury County, Tenn., the practice of subsoiling is popular. Where the subsoil is of a loamy character, as in Christian County, Ky., the practice is not considered profitable.

TABLE V.—*Corn culture in regard to subsoiling, drainage, and tillage before plowing in twenty-one regions of the United States.*

Region covered (fig. 1).		Subsoiling.				Drainage (farmers reporting).			Tillage before plowing.				
Key letter.	County and State.	Farmers practicing.	Time.	Average depth.	Farmers reporting—		Surface.	Part tilled.	All tilled.	Farmers practicing.	Farmers using—		
					For.	Against.					Stalk-cut-ter.	Disk har-row.	Log drag.
		Per cent.		In.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.
A	Tipton, Ind.								100	3.4		3.4	
B	Montgomery, Ohio								100	3.4		3.4	
C	Mercer, N. J.							21.9	46.9	3.1		3.1	
D	Moultrie, Ill.					3.4			100	44.0	3.4	40.7	
E	Tama, Iowa.						36.0	44.0	20.0	32.0		32.0	
F	Kalamazoo, Mich.						34.6	3.8					
G	Maury, Tenn.	40.0	Fall.	12	33.3		93.3	6.7					
H	Hartford, Conn.						68.0	12.0	20.0				
I	Bradford, Pa.						67.9	7.1					
J	Christian, Ky.	15.4	Fall.	12		11.5	38.5			3.8		3.8	
K	Hamilton, Nebr.						4.0			76.0	24.0	72.0	
L	Rockwall and Grayson, Tex.						87.5						
M	Scotland, N. C.	5.3	Fall.	11	15.8	5.3	679.0	18.0		100	79.0	50.0	
N	Augusta, Va.	3.6	do.	12	3.6	3.6	85.6	14.3					
O	Waushara, Wis.						30.0						
P	Bates, Mo.	4.0	Spring.	14	4.0		32.0	8.0		44.0		44.0	
Q	Alexander, N. C.						100			7.1		7.1	
R	Oklahoma, Okla.				4.8		9.5			9.5	9.5		
S	Pike, Ala.	33.3	Spring.	10		4.8	100			71.4	71.4		
T	Holmes, Miss.	4.0		11		4.0	60.0			32.0	16.0	20.0	4
U	Russell, Kans.						40.0			60.0		60.0	

^a Open ditches.

Three principal types of drainage are practiced in the areas surveyed, namely, surface drainage, open ditches, and tiling. Surface drainage is practiced mostly in the rolling areas and where the soils are low in organic matter. The principal object of such drainage is to prevent erosion. This is accomplished by shallow surface ditches or terraces, which convey the surface water from the fields. These ditches are run with the contours and have enough fall to convey the water rapidly, but not enough to cause erosion. The terraces have less fall than the ditches and the water is conveyed more slowly. Occasionally surface ditches are employed in the bottom lands to carry off the surface water. In some areas the rolling lands are drained by surface ditches and the bottom lands tile drained, as in Tama County, Iowa.

In Scotland County, N. C., and a part of Waushara County, Wis., the low lands are drained by deep, open ditches which surround the fields. These ditches collect the seepage water and answer the same

purpose as tile drains, but occupy much land that might be cultivated if tiling were used. It is probable that this land will be tiled when the relative value of the land occupied by the open ditches is equal to the cost of the tiles.

Tile drainage is practiced extensively only on the most productive soils where land values are extremely high, as in the corn belt of Indiana and Illinois.

Tillage before plowing is practiced most often to break up the stalks left from the previous crop. Where the stalks (mostly cotton and corn) grow rank, better plowing can be done and this vegetable matter decays more quickly if broken up before plowing. These stalks are usually cut with a disk harrow or stalk cutter (fig. 3). In a few localities tillage before plowing is practiced to conserve moisture and to prevent the land from breaking up cloddy, as in western Kansas, where the land is harrowed with a disk in the spring and the corn is planted with a lister without further preparation.

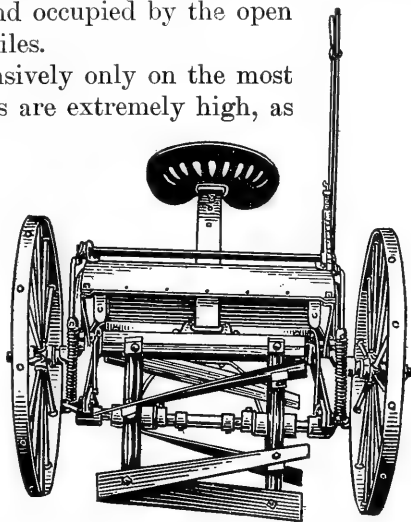


FIG. 3.—A stalk cutter. This implement is used, before plowing, for chopping up stalks and other vegetable matter on the land.

PLOWING.

The choice of time for plowing, whether in the fall or spring, is governed largely by the character of the crop which occupies the land the previous year and by the type of soil. When corn follows sod, more land is generally plowed in the fall than when corn follows some cultivated crop. When land is plowed in the fall it is usually broken deeper than when plowed in the spring.

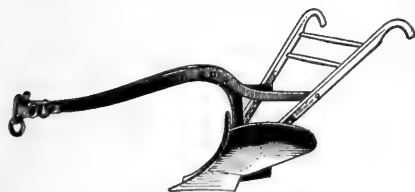


FIG. 4.—A lister, or middle buster, an implement extensively used in the south-western corn States.

In some sections corn land is plowed in the fall and replowed in the spring before planting. This practice is recorded in Table VI under "Fall and spring plowing." In a few sections the land is sometimes plowed in the fall and then listed in the spring with either a middle buster (fig. 4) or a combined lister and planter (fig. 15), which is almost equivalent to rebreaking. This practice is quite general in the Texas and Oklahoma areas and to some extent in the Kansas area.

TABLE VI.—*Preparation for corn, showing farm practices in regard to times and depth of plowing and the use of plows of various sizes in twenty-one regions of the United States.*

[The key letters under "Region covered" refer to counties and States as follows: A=Tipton, Ind.; B=Montgomery, Ohio; C=Mercer, N. J.; D=Moultrie, Ill.; E=Tama, Iowa; F=Kalamazoo, Mich.; G=Maury, Tenn.; H=Hartford, Conn.; I=Bradford, Pa.; J=Christian, Ky.; K=Hamilton, Nebr.; L=Rockwall and Grayson, Tex.; M=Scotland, N. C.; N=Augusta, Va.; O=Waushara, Wis.; P=Bates, Mo.; Q=Alexander, N. C.; R=Oklahoma, Okla.; S=Pike, Ala.; T=Holmes, Miss.; U=Russell, Kans.]

Region covered (fig. 1).	Fall plowing.			Spring plowing.			Fall and spring plowing.		Farmers turning furrows—		Farmers using plows drawn by—				
	Farmers practicing.	Month.	Average depth.	Farmers practicing.	Month.	Average depth.	Farmers practicing.	Average depth.	Over.	On edge.	1 horse.	2 horses.	3 horses.	4 horses.	5 horses.
	P. c.		In.	P. c.		In.	P. c.	In.	P. c.	P. c.	P. c.	P. c.	P. c.	P. c.	P. c.
A	24.1	Nov.	6.5	75.9	Mar., Apr.	6.7	---	---	100	---	---	6.9	82.8	6.9	3.4
B	10.3	Nov., Dec.	7.5	89.7	Mar.-May.	7.4	---	---	96.6	3.4	---	27.6	69.0	3.4	---
C	28.1	do.	6.3	71.9	Jan., Mar., Apr.	6.3	---	---	96.9	3.1	---	50.0	34.4	15.6	---
D	32.2	Sept., Oct.	5.7	67.8	Apr., May.	5.3	---	---	88.1	11.9	---	1.7	28.8	67.8	1.7
E	12.0	Oct.	5.0	88.0	do.	4.8	---	---	100	---	---	---	56.0	40.0	4.0
F	3.8	do.	7.0	96.2	do.	6.6	---	---	100	---	---	7.7	61.6	26.9	3.8
G	46.7	Sept., Nov.	7.9	40.0	Mar.	7.7	13.3	7.5	5.0	100	---	60.0	40.0	---	---
H	8.0	Oct.	7.0	92.0	Apr., May.	7.4	---	---	100	---	---	76.0	24.0	---	---
I	21.4	Oct., Nov.	6.7	78.6	do.	6.0	---	---	100	---	3.6	71.4	25.0	---	---
J	53.8	Nov.	7.2	38.5	Apr.	6.6	7.7	9.0	7.0	100	---	23.1	76.9	---	---
K	8.0	Oct., Dec.	6.0	92.0	Mar., Apr.	5.8	---	---	100	---	---	---	4.0	96.0	---
L	33.3	Sept., Dec.	6.8	37.5	Jan., Feb.	5.6	29.2	6.7	7.0	100	---	25.0	4.2	74.9	8.3
M	0	do.	---	94.7	Jan.-Apr.	5.3	5.3	10.2	5.0	39.5	60.5	23.7	78.9	2.6	---
N	28.6	Nov., Dec.	8.6	71.4	do.	7.8	---	---	100	---	---	71.4	28.6	---	---
O	50.0	Oct., Nov.	5.5	50.0	May	5.5	---	---	100	---	---	42.3	50.0	7.7	---
P	40.0	do.	6.0	60.0	do.	5.7	---	---	100	---	---	12.0	32.0	56.0	---
Q	7.1	Nov.	6.0	57.2	Mar., Apr.	5.9	35.7	7.8	4.0	92.9	7.1	35.7	100	---	---
R	0	do.	---	81.0	Jan.-Apr.	5.1	19.0	6.2	4.8	47.6	23.8	42.8	57.1	14.3	---
S	4.8	Nov.	10.0	90.5	Jan.-Mar.	6.3	4.8	10.0	4.0	28.6	71.4	61.9	42.8	---	---
T	4.0	do.	8.0	88.0	do.	4.8	8.0	6.0	4.0	12.0	88.0	40.0	68.0	---	---
U	4.0	do.	5.0	96.0	Mar., Apr.	5.3	---	---	12.0	88.0	---	---	100	---	---

a Engine and gang plow.

In sections where little vegetable matter is plowed under, a type of plow is often used which leaves the furrow slice on edge instead of completely turning it over. This practice of edging the furrows is very common where 1-horse plows (fig. 5) are used, as in the hill regions of Alabama and Mississippi, or where middle busters and listers are used for breaking, as in Kansas, Texas, and Oklahoma.

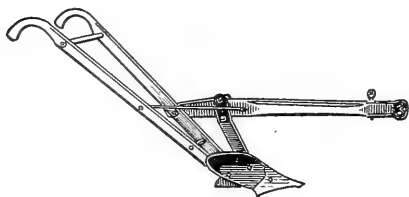


FIG. 5.—A 1-horse turning plow, commonly used for breaking land in the Southern States.

The depth of breaking land is largely governed by the type of soil. Sandy or loam soils, unless underlain with stiff subsoil, are usually broken deeper than the heavy clay soils.

The size of plows used is regulated by the type of farming practiced, the topography, the type of soil, and the general prosperity and condition of the community. In the South Atlantic States crops are grown which require much hand labor. Loamy soils predominate

and land is comparatively cheap. Here 1-horse teams (fig. 6) and 2-horse teams are largely used for plowing. In the Central Western



FIG. 6.—Plowing with 1-horse turning plows. These implements are often used in the Southern States for breaking land.



FIG. 7.—A 2-horse turning plow with chain attached, as used in Waushara County, Wis., to turn a heavy growth of vegetable matter.

States a more extensive type of farming is practiced. The land is level, clay soils predominate, and land values are high. Here heavier teams (fig. 7) are used.

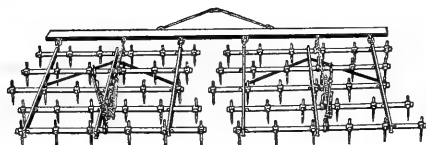


FIG. 8.—A spike-tooth harrow, an implement in general use to prepare the seed bed, after plowing, for corn.

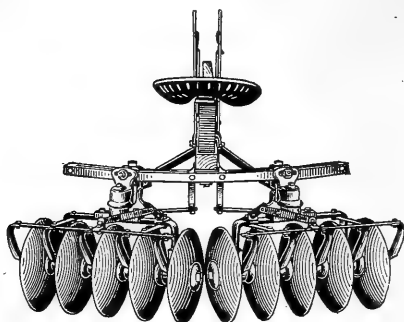


FIG. 9.—A disk harrow, an implement extensively used for preparing the seed bed, after plowing, for corn.

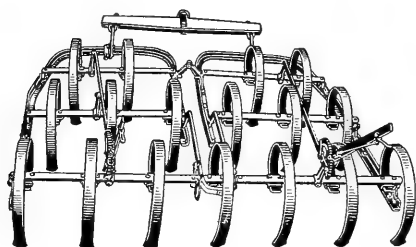


FIG. 10.—A spring-tooth harrow, used extensively in Michigan, Pennsylvania, and New Jersey in preparing the seed bed, after plowing, for corn.

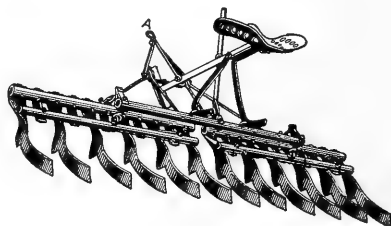


FIG. 11.—An acme harrow, an implement especially adapted for thoroughly pulverizing the seed bed for corn. The evener is attached at A.



FIG. 12.—A spring-tooth harrow, showing its use in preparing sandy-loam land, after plowing, for corn.

TILLAGE IMPLEMENTS USED AFTER PLOWING AND BEFORE PLANTING.

Table VII is presented to show what implements are used in preparing the land for corn after plowing and to show where and to what extent each implement is used. The kind of implement used is governed by the type of farming practiced, the topography of the land, and the type of soil.



FIG. 13.—A plank drag, an implement used in some regions instead of a roller to prepare cloddy land for corn.

The spike-tooth harrow (fig. 8) is extensively used in almost every region visited.

The disk harrow (fig. 9) is also extensively used, but where the land is extremely rolling or stony the spring-tooth harrow (fig. 10) is more popular. The acme harrow (fig. 11) is used only on soils free from stones, but is well adapted for thoroughly pulverizing the seed bed on such soils. The spring-tooth harrow is also often used on loamy soils (fig. 12). The plank drag (fig. 13) and roller (fig. 14) are used on soils which easily become cloddy and to compact light, porous soils. For the more pro-

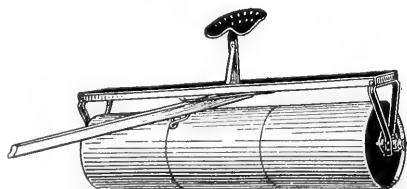


FIG. 14.—A land roller, an implement used for preparing the seed bed, and to compact light, porous soils, after plowing, for corn.

ductive soils more time is given to preparing the land before planting than where the soil is less productive.

TABLE VII.—*Preparation of the seed bed for corn, showing tillage practices, implements used after plowing and before planting, and average number of workings in twenty-one regions of the United States.*

[The key letters under "Region covered" refer to counties and States as follows: A=Tipton, Ind.; B=Montgomery, Ohio; C=Mercer, N. J.; D=Moultrie, Ill.; E=Tama, Iowa; F=Kalamazoo, Mich.; G=Mauzy, Tenn.; H=Hartford, Conn.; I=Bradford, Pa.; J=Christian, Ky.; K=Hamilton, Nebr.; L=Rockwall and Grayson, Tex.; M=Scotland, N. C.; N=Augusta, Va.; O=Waushara, Wis.; P=Bates, Mo.; Q=Alexandria, N. C.; R=Oklahoma, Okla.; S=Pike, Ala.; T=Holmes, Miss.; U=Russell, Kans.]

Region covered (fig. 1).	Harrow.								Roller.	Plank drag.	Turning plow for bedding.	To lay off rows.				Other implements.		Workings.			
	Spike-tooth.		Disk.		Spring-tooth.		Acme.					1-horse single-shovel plow.		Lister.							
	Farms using.		Farms using.		Farms using.		Farms using.		Farms using.		Farms using.		Farms using.		Farms using.						
	All work.		All work.		All work.		All work.		All work.		All work.		All work.		All work.						
A	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.		
B	89.7	33.3	93.1	38.3	13.8	4.9			44.8	16.1	13.8	4.9								2.8	
C	82.8	30.4	69.0	32.4	41.4	20.0			44.8	17.2										3.6	
D	93.7	30.6	65.6	30.6	40.6	14.4	18.7	7.3	6.2	1.8	53.2	15.3								3.5	
E	91.5	38.3	91.5	50.0					33.8	11.7										3.0	
F	100	59.5	92.0	40.5																3.0	
G	53.8	16.1	3.8	1.2	100	49.4			96.2	33.3										3.3	
H	66.7	26.8	100	65.9			6.7	2.5	6.7	4.9										2.7	
I	72.0	34.4	76.0	44.3			36.0	18.0			8.0	3.3								2.4	
J	28.6	11.3	3.6	1.4	100	84.5			7.1	2.8										2.5	
K	80.7	28.6	100	66.2					15.4	5.2										3.0	
L	96.0	63.5	84.0	34.9					4.0	1.6										2.6	
M	66.7	59.4	4.2	2.7									4.2	2.7			33.3	21.6	b 20.8	13.5	1.5
N	13.2	6.8	26.3	12.5									52.6	22.7	86.9	39.8	18.4	8.0	c 26.3	11.4	2.3
O	28.6	9.6	60.7	26.5	85.5	54.2			24.8	9.6										3.0	
P	100	60.4	69.2	39.6																1.8	
Q	100	63.7	56.0	29.2					16.0	7.1										2.3	
R	78.6	87.5	14.3	12.5																1.1	
S	52.4	38.7	9.5	6.5													14.3	9.7	b 66.7	45.1	1.5
T	52.0	38.2	20.0	14.7			4.0	2.9			4.0	2.9	28.0	20.6	20.0	14.7	8.0	5.7	b 100	100	.6

^a Six-horse combination harrow and drag.

^b Lister and planter combined.

^c Cultivators.

METHODS OF PLANTING AND KINDS OF PLANTERS USED.

Whether corn is planted level, on beds, or listed depends largely on climatic conditions and on the type of soil. Throughout the Central Western and Northern States corn is generally planted level. (Table VIII.) Where land is poorly drained corn is sometimes planted on beds. In the Southern and Southwestern States, where light soils predominate and where hot and dry weather often prevails during the growing season, corn is frequently planted in the bottom of the furrow several inches below the surface level. This process is known as listing. This furrow is usually made with a double moldboard type of plow, known as a middle buster or lister (fig. 4), which throws the dirt to both sides. In the Texas, Oklahoma,

and Kansas areas a combined lister and planter (fig. 15) is frequently used. A form of listing often employed in some of the Southern States, where 1-horse plows are largely used, is to throw the land into beds as it is broken and plant the corn in the water furrow between the beds.

TABLE VIII.—*Dates and methods of planting corn, showing the kinds of planters used in twenty-one regions of the United States.*

[The key letters under "Region covered" refer to counties and States as follows: A= Tipton, Ind.; B= Montgomery, Ohio; C= Mercer, N. J.; D= Moultrie, Ill.; E= Tama, Iowa; F= Kalamazoo, Mich.; G= Maury, Tenn.; H= Hartford, Conn.; I= Bradford, Pa.; J= Christian, Ky.; K= Hamilton, Nebr.; L= Rockwall and Grayson, Tex.; M= Scotland, N. C.; N= Augusta, Va.; O= Waushara, Wis.; P= Bates, Mo.; Q= Alexander, N. C.; R= Oklahoma, Okla.; S= Pike, Ala.; T= Holmes, Miss.; U= Russell, Kans.]

Region covered (fig. 1).	Date.		Farmers planting—						Farmers using planter—					
	Average.	Range.	Level.	On beds.	Listing.	Between beds.	In checks.	In drills.	Hand.	1-horse.	2-horse.		3-horse 1-row.	4-horse 1-row.
											2-row.	1-row.		
A	May 9	May 1 to 20.....	P. ct. 96.6	P. ct.	P. ct. 3.4	P. ct. 86.2	P. ct. 13.8	P. ct. 100	P. ct. 100	P. ct. 100	P. ct. 100	P. ct. 100	P. ct. 100	P. ct. 100
B	May 11	April 30 to May 25.....	65.5		34.5	3.4	96.6	100	100	100	100	100	100	100
C	May 10	April 28 to June 2.....	93.7		6.3	71.9	28.1	46.9	53.1	100	100	100	100	100
D	May 17	May 3 to June 14.....	100			100			100	100	100	100	100	100
E	May 12	May 1 to 30.....	100			100			100	100	100	100	100	100
F	do.	May 5 to 20.....	100			96.2	3.8		100	100	100	100	100	100
G	Apr. 15	Mar. 15 to June 10.....	86.7		13.3		100	20	80	16	48	24	24	24
H	May 23	May 5 to June 10.....	100			20	80	16	48	24	24	24	24	24
I	May 26	May 10 to June 6.....	100			32.1	67.9	50	11.3	35.7	100	100	100	100
J	Apr. 22	Apr. 1 to May 25.....	100			73.1	26.9	13.6	4.6	81.8	100	100	100	100
K	May 14	May 9 to 25.....	96		4	96	4	5	100	100	100	100	100	100
L	Mar. 17	Feb. 25 to Apr. 25.....	41.6	12.5	37.5	8.4	12.5	87.5	4.2	8.4	41.6	41.6	4.2	4.2
M	Apr. 7	Mar. 10 to May 18.....			10.5	89.5		100	2.6	97.4				
N	Apr. 29	Apr. 20 to May 11.....	100			39.3	60.7	3.6	17.8	78.6				
O	May 16	May 10 to 27.....	100			50	50	38.5		61.5				
P	May 10	Apr. 15 to May 20.....	88		12	88	12		100	100				
Q	Apr. 18	Apr. 7 to 30.....	100				100	64.3	35.7					
R	Apr. 5	Mar. 5 to May 1.....	9.5		90.5	4.8	95.2	23.8	23.8	33.4	4.7	14.3		
S	Mar. 22	Mar. 3 to Apr. 5.....	19	81		100	42.9	57.1						
T	Apr. 5	Mar. 1 to July 24.....	8	36	8	48	100	56	44					
U	May 6	Apr. 15 to May 25.....	100		100		100						100	

Whether corn is planted in checks or drilled depends largely on the extent corn is grown, on the size and shape of the fields, and on the topography of the land. Where the topography will permit and corn is extensively grown, it is usually planted in checks, because it can be kept free from weeds and cultivated easier in this way. Where listing (fig. 16) is practiced the corn is seldom checked. If planted level it may be checked or drilled.

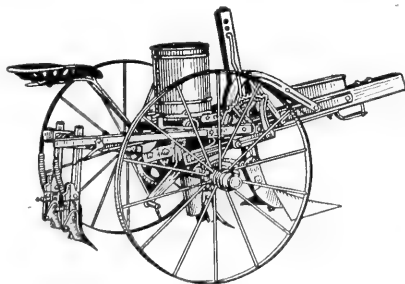


FIG. 15.—A combined lister and corn planter, an implement extensively used in Texas, Oklahoma, and Kansas.

The kind of planter used depends largely on the extent to which corn is grown and on the general prosperity of the region. Where

corn is not extensively grown and where labor is cheap, the planting is usually done by hand or with a 1-horse planter (fig. 17). When



FIG. 16.—Planting corn by the modified form of listing. The row is plowed out with a shovel plow attached to the cultivator. The shovel is run twice for each row and corn is planted in the bottom of this furrow. By using a cultivator with the two shovels attached for laying off the rows, a uniform width of row is maintained.

planted by hand, either a hand planter (fig. 18) is used or the rows are run out with a plow, the corn dropped by hand (fig. 19) and the covering is done with a plow, with a hoe, or with the foot. Where corn is extensively grown and the land is level, a 2-horse checkrow planter that drops and covers two rows at once (fig. 20) is almost

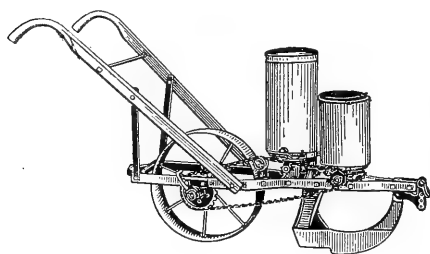


FIG. 17.—A 1-horse corn planter, in use where the crop is not extensively grown.

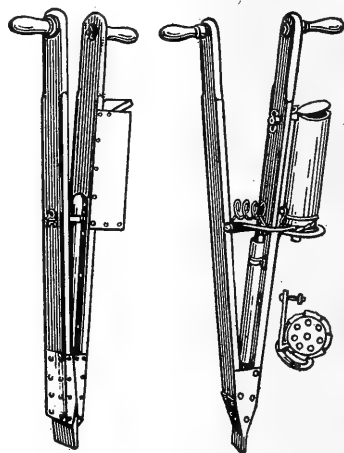


FIG. 18.—Hand corn planters, or bill picks, a type of implement used where labor is cheap.

universally used. Where a lister is attached to the planter, only 1-row planters are used and the number of horses required de-

depends on the size of the lister, the depth of listing, and the kind of soil.

PLANTING, REPLANTING, AND HAND CULTIVATION.

Whether corn is planted in drills or checks depends principally on the topography of the land and the extent to which the crop is



FIG. 19.—Planting corn in Scotland County, N. C., without the use of a planter. The row is laid off with a 1-horse plow, the corn dropped by hand, and the covering done with a plow, with a hoe, or with the foot.

grown. If the land is level and corn is extensively grown it is usually planted in checks, as in the Central Western States. Where the land is rolling or where corn is a minor crop, as in the Southern States, it is usually planted in drills. Where corn is planted in checks more cultivation is given than where it is planted in drills. (Table IX.)

The thickness of planting depends on the fertility of the soil. On the most productive soils corn is planted thickest.

The hand labor consists largely in chopping out weeds and replanting missing hills. This is usually done at the first or second cultivation. In the regions where crops requiring considerable hand labor predominate, as in the cotton-growing States, more hand labor is employed for the corn crop.

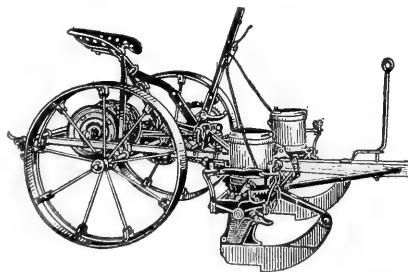


FIG. 20.—A 2-horse checkrow corn planter, for dropping and covering two rows at once, used on level land where the crop is extensively grown.

TABLE IX.—*Corn culture in regard to planting, replanting, average number of cultivations, and yields per acre in twenty-one regions of the United States.*

Key letter.	Region covered (fig. 1). County and State.	Farmers planting in—		Drill averages.				Check averages.				Farmers practicing—		Cultivations.	Normal yield per acre.
		Drills.	Checks.	Between rows.	Between hills.	Stalks per hill.	Space per stalk.	Between rows.	Between hills.	Stalks per hill.	Space per stalk.	Replanting.	Hand cultivation.		
		<i>P. ct.</i>	<i>P. ct.</i>	<i>Feet.</i>	<i>Feet.</i>		<i>Sq. ft.</i>	<i>Feet.</i>	<i>Feet.</i>		<i>Sq. ft.</i>	<i>P. ct.</i>	<i>P. ct.</i>		<i>Bu.</i>
A	Tipton, Ind.	13.8	86.2	3.5	1.2	1	4.2	3.5	3.5	2.5	4.9	0	10	5.5	57.4
B	Montgomery, Ohio.	96.6	3.4	3.4	1.3	1	4.4	3.5	3.7	4	3.2	17.3	55.1	4	52.3
C	Mercer, N. J.	28.1	71.9	3.8	1.2	1	4.6	3.9	3.8	3	4.9	68.7	75	5.9	51.1
D	Moultrie, Ill.	100						3.4	3.4	2.4	4.8	1.7	35.6	4.4	49.3
E	Tama, Iowa.	100						3.5	3.5	3	4.1	24	24	5.3	46.6
F	Kalamazoo, Mich.	3.8	96.2	3.7	1	1	3.7	3.7	3.7	2.5	5.5	7.7	26.9	5	41.5
G	Mauzy, Tenn.	100		3.7	1.4	1	5.2					13.3	16.7	5.4	40.9
H	Hartford, Conn.	80	20	3.4	2.1	3.4	2.1	3.3	3.3	4.2	2.5		68	3.8	39.9
I	Bradford, Pa.	67.9	32.1	3.3	9	1.4	2.1	3.3	3.3	3.7	2.9	25	71.4	4.4	38.2
J	Christian, Ky.	26.9	73.1	3.7	1.7	1	6.3	3.7	3.8	2.1	6.7	7.7	15.4	5.1	36.9
K	Hamilton, Nebr.	4	96	3.5	1.2	1	4.2	3.5	3.5	2.6	4.7	8	8	5.1	35
L	Rockwall and Grayson, Tex.	87.5	12.5	3.4	2.1	1.1	6.5	3.6	3.5	1.5	8.4	4.1	87.5	3.9	33.6
M	Scotland, N. C.	100		5.5	1.6	1.3	6.8					76.3	81.6	4.3	33
N	Augusta, Va.	60.7	39.3	3.5	1.8	1.2	5.2	3.5	3.6	2	6.3	42.8	82.1	4.1	33
O	Waushara, Wis.	50	50	3.5	1.1	1.1	3.5	3.5	3.5	2	6.1	3.8	3.8	5.4	30.4
P	Bates, Mo.	12	88	3.5	1.3	1	4.6	3.5	3.6	2.5	5	40	40	4.8	29.3
Q	Alexander, N. C.	100		4.1	2.1	1	8.6					71.4	92.9	5.1	25.2
R	Oklahoma, Okla.	95.2	4.8	3.5	1.4	1	4.9	3.5	3.5	2	6.1	4.8	42.8	3.9	23.9
S	Pike, Ala.	100		5.3	2	1.4	7.6					52	66	4.7	23.1
T	Holmes, Miss.	100		3.8	2.2	1.3	6.4					30	72	4.7	22
U	Russell, Kans.	109		3.5	1.6	1	5.6							3.8	20.4

GENERAL FARM PRACTICES AND CONDITIONS.

SURVEYS IN TIPTON COUNTY, IND.

The tillage records for Indiana were taken in the central part of Tipton County (Table X). This is in the corn-belt prairie section (fig. 1, A). The soil is a silty clay loam about 8 inches deep with a heavier clay-loam subsoil. The soils are dark brown to almost black in color and are very productive, especially the darker type. The country is very flat and appears as a continuous plain.

Many improvements have been made in this county. Practically all the land has been tile drained, the farmers having cooperated in establishing central drainage systems to dispose of the water. Exceptionally good roads are maintained. Every section line is a public road and nearly all the roads have been graveled. A system of central schools has been established to take the place of the local county schools. The land is worked mainly by the owners. The farmers live in good houses and have well-kept barns and outbuildings, which give to the country a very prosperous appearance.

The farm practices for the section are very uniform. Most farmers maintain a general rotation of corn one year, wheat or oats one year, and hay or pasture one or two years. Some timothy is grown, but most of the hay is clover. Considerable truck, such as garden peas, tomatoes, and sweet corn, is grown for the canning factories.

A few pear orchards are found, but very little fruit is grown except for home use. Hogs are extensively raised and furnish one of the principal sources of farm income. Numerous cattle, mostly of the beef type, are kept.

TABLE X.—*Tillage practices with corn in Tipton County, Ind., showing depth of plowing, implements used in order of use, number of times each is used, and normal yield of the crop.*

[In columns 3 to 8 and 10 to 16 the figures show the order in which the implement was used on the several farms; as, 1 = first working or cultivation, 2 = second working or cultivation, etc.]

Farm No.	Depth of plowing (inches).	Tillage after plowing and before planting.								Tillage after planting.										Normal yield per acre (bushels).
		Harrow.				Plank drag.	6-horse combined harrow and drag.	All workings.	Spike-tooth harrow.	Roller.	Cultivator.				Mower wheel.	Harrow, weeder, or roller.	Total cultivations.			
		Disk.	Spring-tooth.	Spike-tooth.	Roller.						2-horse 4-shovel.	Spring-tooth 10-shovel.	2-horse 8-shovel.	2-horse 6-shovel.			Other imple-ments.	All workings.		
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	
1	7	1		3	2			3	1					2 to 5		1	4	5	50	
2	6	1		3	2			3		1				2, 3, 4		1	3	4	60	
3	8	1		3	2			3	1					2 to 5		1	4	5	60	
4	6	1		2	2			2	2	1				3, 4, 5		2	3	5	50	
5	6	1		3	2			3	1	2			3 to 7			2	5	7	50	
6	7	1		3	2			3			1 to 4				5		5	5	45	
7	7	1				2		2	1	2				3 to 6		2	4	6	75	
8	7		1		2	3		3		1, 3				2 to 6		2	4	6	60	
9	6	1		2				2	1					2 to 5		1	4	5	50	
10	7	1		2, 4		3		4	1	2				3 to 6		2	4	6	50	
11	5	1		2				2	1					2 to 5		1	4	5	65	
12	6	1, 2		4		3		4	1	2				3 to 7		2	5	7	50	
13	6	1, 2		3				3	1	2				3, 4, 5	6	2	4	6	60	
14	5	1		3	2			3	1			2		3, 4, 5		1	4	5	50	
15	8	1	3	2			4	4	2	1			2	3 to 6		2	4	6	55	
16	7	1		2				2	1					2 to 5		1	4	5	60	
17	7	1		2				2	2	1, 4			3, 5, 6, 7		8	3	5	8	65	
18	7		1	2	3			3		1, 2			3, 4, 5			2	3	5	60	
19	7	1		3	2			3		1				2 to 5		1	4	5	50	
20	6	1, 2		3				3	1	2				3 to 6		2	4	6	60	
21	6	1	2					2	1	2				3 to 6		2	4	6	55	
22	7	1		2	3			3	1					2, 3, 4		1	3	4	65	
23	8	1		2				2	2	1				3 to 7		2	5	7	60	
24	7½	1		3	2			3	1				2 to 5			1	4	5	60	
25	7	1		2				2	1				2, 3, 4			1	3	4	50	
26	8	1		2				2		1				2 to 5		1	4	5	50	
27	7	1, 2		4		3		4	1	2				3 to 6		2	4	6	75	
28	6	1		3	2			3	1	2			3 to 6			2	4	6	75	
29	6	1		3	2			3	1					2, 3, 4		1	3	4	50	
Farms using, per cent.		93.1	13.8	89.7	44.8	13.8	6.9		79.3	62.1	3.4	3.4	20.7	75.9	10.3	96.6				
Average	6.7							2.8									3.9	5.5	57.4	

a Plank drag.

About 75 per cent of the corn land is broken in the spring. Three-horse sulky plows (fig. 21) are largely used for breaking. The usual custom of preparation is to follow the plow with the disk harrow, then roll, and harrow with the spike-tooth harrow before planting. The planting is done with the 2-horse 2-row planter and the corn

is planted in checks $3\frac{1}{2}$ feet apart each way, alternating the hills with two and three kernels.

After planting, the field is usually gone over with the spike-tooth harrow or roller, first before and again after the corn is up. After this most of the cultivating is done with the 2-horse 6-shovel cultivator (fig. 22). The customary practice is to give four cultivations in alternate directions.

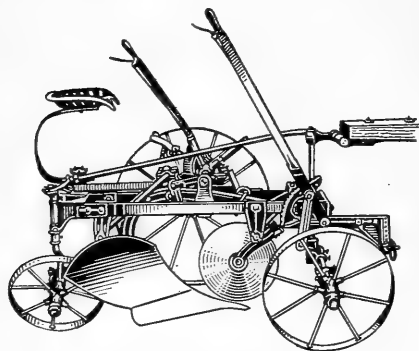


FIG. 21.—A sulky plow (for either two or three horses) used in the Central West.

Few cover crops are grown and the corn land is usually either seeded to wheat in the fall or oats the following spring. Very little commercial fertilizer is used, but stable manure is frequently applied broadcast to the land before breaking for corn. The corn is mostly of the yellow dent varieties, but some white dent is grown.

The most prevalent weeds for this section are foxtail, quack-grass, smartweed, plantain, ragweed, cocklebur, whitetop, and bull nettle.

SURVEYS IN MONTGOMERY COUNTY, OHIO.

The tillage records for Montgomery County, Ohio, were taken in the section around Brookville, in the northwestern part of the county. (Table XI.) The soil is of a silty clay-loam character with a clay subsoil. The land is rolling enough to allow good drainage, but not steep enough to interfere with the use of improved machinery, and the fields are of uniform size and convenient shape. Most of this land is tile drained and only a few surface ditches are necessary.

The leading roads have been macadamized. Good country schools are maintained. Most of the farms are rather small and are operated by the owners. They have exceptionally good farmhouses and outbuildings, and the country has a very prosperous appearance.

A very uniform system of farming is practiced in this section. On most farms a rotation of corn or tobacco one year, wheat or oats one year, and hay or pasture one or two years is maintained. Some alfalfa is grown with good results. Considerable red and alsike clover seed is produced. Little or no fruit is grown for market and

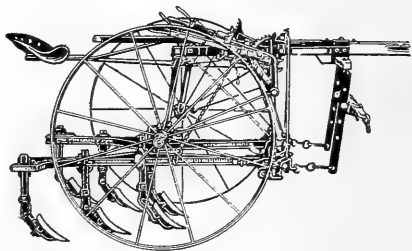


FIG. 22.—A 2-horse 6-shovel corn cultivator.

little truck is produced. Hogs and cattle are extensively grown, but tobacco and wheat are the leading money crops.

Corn is usually grown on sod land, and in preparing for corn most of the breaking is done in the spring with a 3-horse sulky plow and immediately harrowed with a spike-tooth or disk harrow. Then before planting, the land is harrowed again with the spike-tooth harrow and rolled. The corn is usually planted in drills, with a 2-horse 2-row planter. The rows are usually $3\frac{1}{2}$ feet apart, with one stalk every 18 inches in the drill.

TABLE XI.—*Tillage practices with corn in Montgomery County, Ohio, showing depth of plowing, implements used in order of use, number of times each is used, and normal yield of the crop.*

[In columns 3 to 6 and 8 to 12 the figures show the order in which the implement was used on the several farms; as, 1 = first working or cultivation, 2 = second working or cultivation, etc.]

Farm No.	Depth of plowing (inches).	Tillage after plowing and before planting.					Tillage after planting.									Normal yield per acre (bushels).
		Harrow.			Roller.	All workings.	Spike-tooth harrow.	Roller.	Cultivator.		Total culti- vations.					
		Spring-tooth.	Disk.	Spike-tooth.					2-horse.		1-horse, 5 shovel.	Harrow, weeder, or roller.	Other im- ple- ments.	All workings.		
									8-shovel.	6-shovel.						
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	
1	6			1, 2	3	3	1		2, 3			1		3	50	
2	8	1, 2, 3				3		1		2, 3, 4		1	3	4	65	
3	6		1, 2	3		3	1			2, 3, 4		1	3	4	75	
4	6½	1				1			1, 2, 3				3	3	40	
5	8		1	2		2			1, 2				2	2	65	
6	7		1			3		1		2, 3, 4		1	3	4	40	
7	7	1		2, 3		3	1	2	3, 4			2	2	4	65	
8	8	2, 4			1, 3, 5	5			1, 2, 3				3	3	45	
9	7		1, 4	3		4			1, 2, 3				3	3	40	
10	7		1	2, 4	3	4				1, 2, 3			3	3	65	
11	7		3, 4	1, 2, 5		5	2, 3	1	4, 5, 6			3	3	6	50	
12	7½		1, 2	3		3	1			2, 3		1	2	3	45	
13	6	1, 2, 5		3, 4		5	1	1		2, 3, 4	5	1	4	5	66	
14	8½		1, 2	3		3	1			2, 3		1	2	3	50	
15	8		1	3		2	3	1		2, 3, 4		1	3	4	50	
16	6½	1, 3, 4				2		1		2, 3, 4		1	3	4	50	
17	7		1, 2	3, 4		4	1	2		3 to 6		2	4	6	70	
18	8		1	2		2			1 to 4				4	4	30	
19	6		1	2		2	1	3	4, 5	2		2	3	5	40	
20	6		1 to 4	5		5	1		2, 3, 4		1	1	3	4	40	
21	7		1, 2, 5	4	3	5	2	1, 3	4, 5, 6			3	3	6	65	
22	6½	2	1	3		4			1, 2, 3				3	3	50	
23	5½	1, 2			3, 4, 5	5			1, 2, 3				3	3	25	
24	7	1, 2		4	3	4			1, 2, 3				3	3	50	
25	7		2	1		2	1			2, 3, 4		1	3	4	50	
26	7½	4	1, 2	6	a 3, 5	6		1		2, 3, 4		1	3	4	65	
27	8	1	3, 4	2		5		1, 3	2	4, 5		2	3	5	60	
28	8		1, 2	3, 4		4	1, 2	a 3		4, 5		3	2	5	50	
29	7	1	2	3		3		1, 3		2, 4, 5		2	3	5	60	
Farms using, per cent.																
Average..	7.1	41.4	69	82.8	44.8	3.6	44.8	44.8	44.8	62	3.4	69	2.9	4	52.3	

a Plank drag.

After planting, the cultivation methods are very uniform. When the corn is up, the field is usually gone over with the spike-tooth harrow or roller and then cultivated three times with a 2-horse 6 or 8 shovel cultivator (fig. 23). The cultivating is generally level.

The yellow dent varieties of corn are usually grown.

Some commercial fertilizer is used and considerable stable manure is produced and applied broadcast. Cover crops are seldom grown.

The most prevalent weeds found in this region are foxtail, ragweed, pigweed, wild carrot, whitetop, and buttonweed.

SURVEYS IN MERCER COUNTY, N. J.

The records for Mercer County, N. J., were taken mostly in the potato-growing sections south of Trenton. (Table XII.) The soil here is principally of a sandy-loam nature, with a clay subsoil. Occasionally this clay is underlain with gravel. The land is rolling

enough to afford good natural drainage, except in the bottoms, where it is necessary to use tile. These bottom lands are practically all tiled. The country is level enough to enable the farmers to have fields of uniform size and shape and to use improved machinery to good advantage.

The county is generally prosperous. Most farmers have good houses, good rural schools are maintained, and the principal roads have been macadamized.

The soil, being of a porous character, is rather low in humus content, and responds readily to

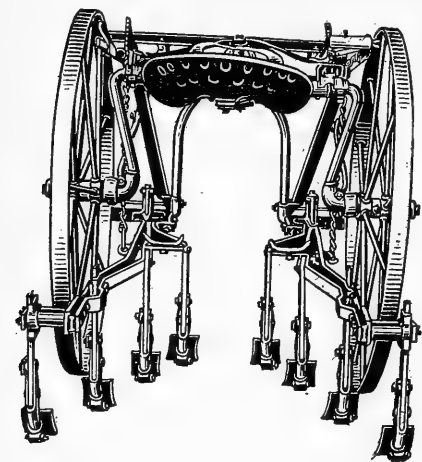


FIG. 23.—A 2-horse, 8-shovel cultivator.

a humus supply of any kind. Large quantities of commercial fertilizer are used on potatoes and corn and mostly applied in the drill before planting.

The tillage practices and rotations are of a rather definite type in this region. Nearly all the farms maintain a rotation of corn one year, potatoes one year, rye or wheat one year, and hay one or two years. Considerable truck and fruit is grown near Trenton and on some farms this furnishes the principal income, but the source of income on most farms is from potatoes and rye.

Corn is usually grown on sod land, and about 75 per cent of the breaking is done in the spring. Most of the land is then harrowed

twice with the disk, acme, or spring-tooth harrow, then with a spike-tooth harrow once, and the plank drag is used once just before planting.

TABLE XII.—*Tillage practices with corn in Mercer County, N. J., showing depth of plowing, implements used in order of use, number of times each is used, and normal yield of the crop.*

[In columns 3 to 7 and 9 to 13 the figures show the order in which the implement was used on the several farms; as, 1 = first working or cultivation, 2 = second working or cultivation, etc.]

Farm No.	Depth of plowing (inches).	Tillage after plowing and before planting.							Tillage after planting.								Normal yield per acre (bushels).
		Harrow.						Spike-tooth harrow.	Weeder.	Cultivator.			Total cultivations.				
		Disk.	Acme.	Spring-tooth.	Spike-tooth.	Plank drag.	All workings.			2-horse.		1-horse 5-shovel.	Harrow, weeder, or roller.	Other implements.	All workings.		
										8-shovel.	With sweeps for ridging.						
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	
1.	8	1			2	3	3			1, 2, 3	4, 5			5	5	40	
2.	8	2, 3			1	4	4		1, 2	3 to 6			2	4	6	50	
3.	7	1, 2			3	4	4		1, 2	3 to 7				5	7	65	
4.	5		1, 2		3	4	4		1	2 to 6			1	5	6	60	
5.	6	1, 2			3	4	4			1, 2	3, 4			4	4	40	
6.	6	1, 2	3		4		4		2	1, 3, 5 to 8		4	1	7	7	50	
7.	6	1		2			3			1 to 4	5, 6			6	6	50	
8.	6	1, 2			3, 4	5	5			1 to 4			5	5	5	40	
9.	7	1, 2			3		2			1 to 4		5, 6, 7		7	7	50	
10.	6				1, 2		2			1 to 4	5, 6			8	8	60	
11.	5	1, 2			3	4	4			1 to 5				5	5	38	
12.	5		2, 3		4	a 1	4	1		2 to 5		6	1	5	6	50	
13.	5		1		2		2			1 to 4	5, 6			6	6	40	
14.	4	1		2	3	4	4	1	3	2, 4, 5			2	4	6	45	
15.	7	1, 2	3		4		4			1 to 6				6	6	50	
16.	7	1		2	3	a 4	4	1		2	4	3, 5, 6	1	5	6	80	
17.	8	1, 2			3, 4		4	1		2 to 5		6, 7	1	6	7	50	
18.	7		1		2		2	1		2 to 6			1	5	6	50	
19.	6		1, 2		3	4	4		1	2, 3, 4		5, 6	1	5	6	70	
20.	7	2	1		3	4	4	1, 2		3, 4, 5		6, 7	2	5	7	60	
21.	7	1		2	3		3			1, 2	3, 4	5, 6		6	6	50	
22.	4½			1, 2	4	3	4	1		2 to 5		6, 7	1	6	7	50	
23.	4½			1	2	3	3			1 to 5				5	5	50	
24.	8	1-4		5			5			1 to 3		4		4	4	60	
25.	6	1			3	2	3		1	2 to 5			1	4	5	40	
26.	8	1			2	3	3			1 to 4		5		5	5	75	
27.	6		1, 2	3	4	4	4			2 to 5	6		1	6	6	40	
28.	6	1		3		2	3	1	3	2 to 7			2	5	7	42	
29.	5			1	2		2			1 to 4	5	6		6	6		
30.	4	1	2		3	4	4			1 to 5				5	5	50	
31.	4				1, 2		2	1		2 to 5			1	4	5	50	
32.	6	1, 2			3		3			1, 2, 3	4, 5			5	5	40	
Farms using... per cent.		65.6	18.7	40.6	93.7	59.4		28.1	25.0	100	31.2	46.8	53.1				
Average.	6.3						3.5							5.3	5.9	51.1	

a Roller.

Nearly all the corn is planted level and about 70 per cent in checks 3½ to 4 feet apart each way, with three kernels per hill. About 50 per cent of the planting is done with a hand planter and the rest with the 2-horse 2-row planter. After planting, about 50 per cent of the farms

use a weeder (fig. 24) or spike-tooth harrow for the first cultivation, and for the next four or five cultivations the 2-horse 8-shovel cultivator is mostly used. The 1-horse 5-shovel 1-row cultivator (fig. 25)

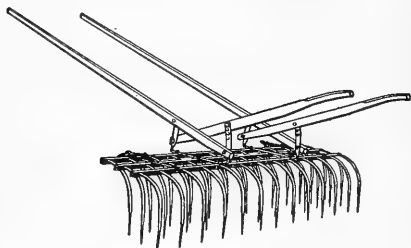


FIG. 24.—A weeder used for the first cultivation of corn.

The most prevalent weeds are crab-grass, smartweed, nut-grass, Canada thistle, ragweed, and purslane.

SURVEYS IN MOULTRIE COUNTY, ILL.

The tillage records for Moultrie County, Ill., were taken near Lovington, which is in the prairie region. (Table XIII.) This section is exceptionally level. The farms are divided into uniform fields,

is often used for the last cultivation. A 2-horse potato plow having four long sweeps and designed for ridging the land is often used for the last cultivation.

About 35 per cent of the farmers grow crimson clover and rye or vetch as cover crops after corn.

The principal varieties of corn grown are of the yellow dent type, but some white dent is grown.

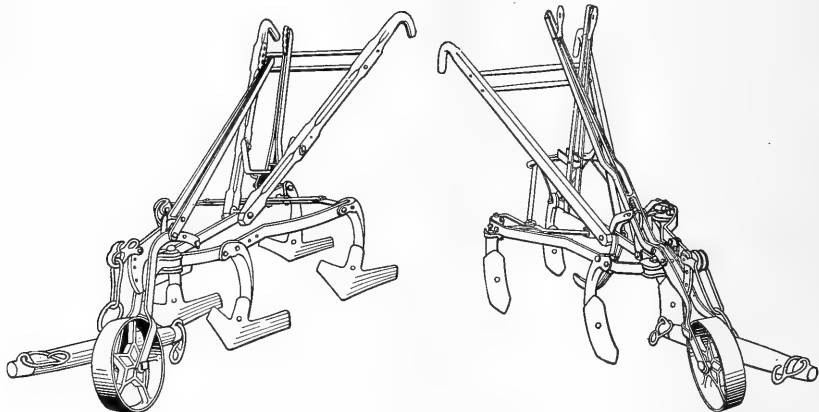


FIG. 25.—A 1-horse 5-shovel corn cultivator; at left with sweeps attached, at right with shovels.

which are well fenced. The farmers appear to be very prosperous, with exceptionally good houses and outbuildings, but only a few of the roads have been improved and hauling is very difficult during wet weather.

The soil is a very dark-colored sticky clay, known as the prairie-loam type, which cakes easily and becomes extremely hard in dry weather, frequently cracking badly. It is very fertile, and practically no commercial fertilizer is used. Nearly all the cultivated

land in this section is tile drained and the farmers have cooperated in establishing central drainage systems to dispose of the drainage water.

TABLE XIII.—*Tillage practices with corn in Moultrie County, Ill., showing depth of plowing, implements used in order of use, number of times each is used, and normal yield of the crop.*

[In columns 3 to 5 and 7 to 12 the figures show the order in which the implement was used on the several farms; as, 1 = first working or cultivation, 2 = second working or cultivation, etc.]

Farm No.	Depth of plowing (inches).	Tillage after plowing and before planting.				Tillage after planting.									Normal yield per acre (bush-els).
		Harrow.			All workings.	Harrow.	Roller.	2-horse cultivator.				Total cultivations.			
		Spike-tooth.	Disk.	Roller.				6-shovel.	4-shovel.	Surface.	Disk (fig. 27).	Harrow, weeder, or roller.	Other imple-ments.	All workings.	
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1.	5	1	2,3	—	3	2	1	—	3,4,5	—	—	2	3	5	55
2.	5	3	1,2	4	4	1,3	2	4 to 7	—	—	—	3	4	7	50
3.	4	3	1	2	3	1	—	4	2,3	—	—	13	3	4	50
4.	4	1,4	2,3	—	4	1	—	2,3	—	4	—	1	3	4	50
5.	4	3	1	2	3	1	—	2,3	—	—	4	1	3	4	50
6.	5	1	—	2	2	2	1	3,4,5	—	—	—	2	3	5	45
7.	6	3	1,2	—	3	2	—	1 to 4	—	—	—	0	4	4	60
8.	5	—	1,2	—	2	1	—	2,3,4	—	—	—	1	3	4	50
9.	4½	2	1	3	3	1,3	2	5	—	4,6	—	3	3	6	48
10.	5	1,2	3	—	3	—	—	1,2,3	—	—	—	0	3	3	45
11.	6	3	1,2	—	3	2	1	—	—	3,4,5	—	2	3	5	45
12.	6	3	1,2	—	3	1	—	2 to 5	—	—	—	1	4	5	45
13.	5	1	2,3	—	3	1	—	2,3	—	—	—	1	2	3	40
14.	5	3	1,2	—	3	1	—	2,3,4	—	—	—	1	3	4	45
15.	5	3	1,2	—	3	1	2	3 to 6	—	—	—	2	4	6	35
16.	5	3	1,2	—	3	1	—	—	—	—	2,3,4	1	3	4	55
17.	7	1,4,5	2,3	—	5	—	1	2,3,4	—	—	—	1	3	4	75
18.	6	1,4	2,3	—	4	—	1	2,3,4	—	—	—	1	3	4	55
19.	6	—	1	—	1	1	—	3,4,5	—	2	—	1	4	5	50
20.	6½	1	3	2	3	1	—	2,4	—	3,5	—	1	4	5	—
21.	7	3	1,2	4	4	—	1	2,3,4	—	—	—	1	3	4	55
22.	5	4,5	1,2,3	—	5	1	—	2,3,4	—	—	—	1	3	4	40
23.	7	2	1	—	2	1	—	2 to 5	—	—	—	1	4	5	50
24.	5	3	1,2	—	3	—	—	1,2,3	—	—	—	0	3	3	50
25.	5½	2,4	—	1,3	4	2	1	—	—	3,4,5	—	2	3	5	45
Farms using, per cent.	—	92	92	32	—	76	44	84	8	24	8	88	—	—	—
Average.	5.4	—	—	—	3.2	—	—	—	—	—	—	—	3.2	4.4	49.5

^a Eight-shovel cultivator.

The farmers in this county generally practice a rotation of corn two years, oats one year, wheat one year, and clover one year. Frequently wheat is omitted from the rotation and clover is seeded with oats. Still more frequently corn is grown for a number of years on the same land without any rotation. Very little fruit or truck is grown in this section and the corn crop is the principal source of income. Some cattle and hogs are sold.

The fields are usually laid off in 40-acre squares and the breaking is done largely with 3 and 4 horse sulky plows. Generally large Percheron mares are worked on the farms and the geldings are sold

for the city trade. These mares average about 1,400 pounds in weight, which permits the use of large implements and requires little man labor.

After the land is broken the seed bed is usually prepared with a 4-horse disk harrow, followed by a corrugated roller (fig. 26), and

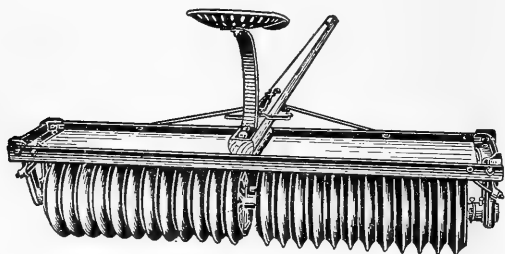


FIG. 26.—A corrugated roller or pulverizer, an implement used in Moultrie County, Ill., and other sections of the Middle West.

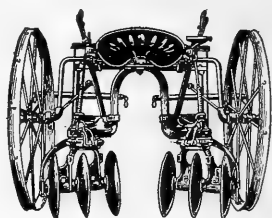


FIG. 27.—A 2-horse disk cultivator used in cultivating corn in Moultrie County, Ill.

this is followed by a spike-tooth harrow. This leaves the land practically level and in very fine condition. Planting is done in most cases with a 2-row edge drop planter in checks $3\frac{1}{2}$ feet apart each way, alternating the hills with two and three grains.

While the corn is coming up, or right after it gets up, the field is harrowed once or twice with a spike-tooth smoothing harrow. If

the field is cloddy, a corrugated roller is used before the harrow. After this harrowing most of the cultivating is done with a 2-horse 6-shovel cultivator or a 2-horse disk cultivator (fig. 27). Usually three or four cultivations are given in alternate directions. A type of implement known as the surface cultivator (fig. 28) is frequently used, especially for the last cultivation. This implement, instead of having shovels, is equipped with four long sweeps, which are very similar to the knives of a stalk cutter. These

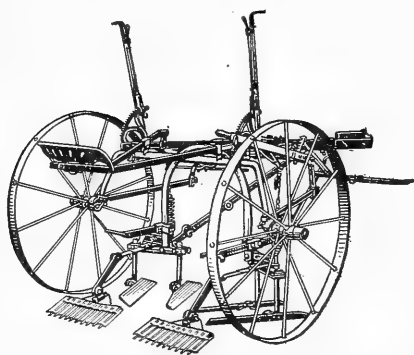


FIG. 28.—A type of surface cultivator equipped with four long sweeps for stirring the soil, used for corn tillage in Moultrie County, Ill., and other sections of the Middle West.

sweeps run two on either side of the row and about 1 inch deep. They are set at an angle to the soil of about 45° . The sweeps cut off and destroy the weed growth much more effectively than do the shovels.

Practically no cover crops are grown in this region. Both the white and yellow dent varieties of corn are grown. The principal troublesome weeds for this section are foxtail, smartweed, cocklebur, morning-glory, and buttonweed.

SURVEYS IN TAMA COUNTY, IOWA.

Tama County is located in east-central Iowa and is a typical corn-growing region. The soil is principally of the silt-loam type and is very productive. The country generally is gently rolling, but some parts of this county are rather hilly. This rolling condition with a loamy type of soil affords good natural drainage except in the bottoms, which are practically all tile drained. The land is usually not too steep for the profitable use of improved machinery. (Table XIV.)

TABLE XIV.—*Tillage practices with corn in Tama County, Iowa, showing depth of plowing, implements used in order of use, number of times each is used, and normal yield of the crop.*

[In columns 3, 4, and 6 to 9 the figures show the order in which the implement was used on the several farms; as, 1 = first working or cultivation; 2 = second working or cultivation, etc.]

Farm No.	Depth of plowing (inches).	Tillage after plowing and before planting.			Tillage after planting.							Normal yield per acre (bushels).
		Harrow.		All workings.	Spike-tooth harrow.	2-horse.			Total cultivations.			
		Disk.	Spike-tooth.			Cultivator.		Weeder.	Harrow, weeder, or roller.	Other imple-ments.	All workings.	
1	2	3	4	5	6	7	8					9	10	11	12	13
1.	5	3	1,2,4	4	1,2	3,4,5			2	3	5	45
2.	5	2	1,3	3	1	2 to 5			1	4	5	40
3.	5	3	1,2,4	4	1,2	3,4,5			2	3	5	45
4.	4	1	2	2		4,5		1,2,3	3	2	5	65
5.	5	1,2	3,4	4	1,2	3 to 6			2	4	6	63
6.	5	1	2,3,4	4	1,2	3,4,5			2	3	5	60
7.	4	1,2	3	3	1,2	3 to 6			2	4	6	45
8.	5	3	1,2	3	1,2,3	4 to 7			3	4	7	40
9.	5	3	1,2	3	1,2,3	4,5,6			3	3	6	45
10.	5	1,2	3,4	4	1,2	3,4,5			2	3	5	45
11.	5		1,2	2	1,2	3 to 6			2	4	6	35
12.	6	1	2	2	1,2	3,4,5			2	3	5	48
13.	6	1	2	2	1,2	3 to 6			2	4	6	30
14.	4	1	2	2	1,2	3 to 6			2	4	6	35
15.	6	1	2,3	3	1,2	3 to 6			2	4	6	45
16.	5	1,2	3,4	4	1	2,3,4			1	3	4	20
17.	4	1	2	2	1,2	3,4	5		2	3	5	40
18.	6	1,2	3,4	4	1,2	3 to 6			2	4	6	50
19.	4	1	2,3	3	1,2	3,4,5			2	3	5	45
20.	3		1,2	2	1,2	3 to 6			2	4	6	50
21.	5	1	2,3	3	1,2	3,4,5			2	3	5	55
22.	7	1,2	3	3	1,2	3,4,5			2	3	5	30
23.	4	1	2	2		1 to 4			0	4	4	40
24.	6	1	2	2	1	2,3,4			1	3	4	40
25.	6	1,2	3,4	4	1,2	3 to 6			2	4	6	60
Farms using, per cent.		92	100		92	100	4	4	96			
Average.	5.1			3						3.4	5.3	46.6

The county generally appears very prosperous. Most of the leading roads have been improved, good schools are maintained, and exceptionally good farmhouses and barns are found. Almost universally the farmhouses are painted white and the barns red.

Almost half the farms are operated by tenants, and usually a cash rent is paid. The average-sized farm is 148.8 acres, with 109.7 acres cultivated, not including the pasture lands. No definite rotations are practiced. The principal crops grown are corn, oats, and hay, with some little wheat. A general rotation of corn two years, oats one year, and hay and pasture two years is practiced to some extent. Not enough fruit is produced to supply home demands. Sweet corn is grown by most farmers living near Toledo, to supply the canning factory located there. Bluegrass does well in this section and pastures are maintained on most farms. Most of the grain grown in this section is fed on the farms to beef cattle and hogs. Some colts are raised and a few farmers keep sheep. The principal source of farm income is from the sale of live stock.

In preparing land for corn heavy teams are generally used. Most of the breaking is done in the spring with a 3-horse sulky plow. Where corn follows sod often a part of the land is broken in the fall. After plowing, the land is usually harrowed with a disk harrow and then just before planting harrowed twice with a spike-tooth harrow. Corn is planted level and a 2-horse 2-row planter is used. The rows are generally $3\frac{1}{2}$ feet apart each way and the hills alternate with two and three grains. The cultivation methods after planting are exceptionally uniform. The corn is harrowed with a spike-tooth harrow before and just after coming up. Then three or four cultivations are given with a 2-horse 6-shovel riding cultivator. Practically no cover crops are grown, and no fertilizer is used other than stable and barnyard manure. Both the yellow and white varieties of dent corn are grown.

The most prevalent weeds in this section are foxtail, bindweed, pigweed, ragweed, smartweed, and cocklebur.

SURVEYS IN KALAMAZOO COUNTY, MICH.

Where the tillage records for Michigan were taken in southern Kalamazoo County, principally around Schoolcraft, the country is level and is known as the prairie section.

This region is prosperous and on most farms are found exceptionally good farmhouses and good outbuildings. Most of the principal roads have been graveled or macadamized. Since the land is practically level the farmers are enabled to have uniform-sized fields and to use improved machinery to advantage. (Table XV.) The soil consists of a dark brown to black loam from 12 to 16

inches deep. The subsoil is of a heavier clay loam to a depth of 3 feet, which is underlain with beds of sand and gravel, affording good natural drainage, which makes tiling unnecessary.

In this region a type of general farming is practiced, with the farm income principally from grain and hogs. A rotation of corn one year, oats one year, wheat one or two years, and hay one year is maintained to some extent, but only a few farms have definite rotations. Very little truck is grown except around Kalamazoo, where numerous muck beds are found. These are principally used for growing celery. A few cattle are kept and the manure is usually applied broadcast to the sod land before breaking for corn. Practically no commercial fertilizer is used.

TABLE XV.—*Tillage practices with corn in Kalamazoo County, Mich., showing depth of plowing, implements used in order of use, number of times each is used, and normal yield of the crop.*

[In columns 3 to 6 and 8 to 11 the figures show the order in which the implement was used on the several farms; as, 1 = first working or cultivation, 2 = second working or cultivation, etc.]

Farm No.	Depth of plowing (inches).	Tillage after plowing and before planting.					Tillage after planting.							Normal yield per acre (bushels).
		Harrow.			Roller.	All workings.	Spike-tooth harrow.	Roller.	Cultivator, 2-horse.		Total cultivations.			
		Spring-tooth.	Spike-tooth.	Disk.					6-shovel.	Spring-tooth.	Harrow, weeder, or roller.	Other implements.	All workings.	
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1.	6	1, 3			2	3			1 to 5			5	5	40
2.	6½	2, 3			1	3			1 to 6			6	6	60
3.	6	2, 3			1	3			1 to 4			4	4	40
4.	7	1, 2, 3			4	4	1		2 to 5		1	4	5	40
5.	7	1, 2	3		4	4			1 to 6			6	6	30
6.	6½	3, 4	2		1	4			1 to 6			6	6	40
7.	7	2			1	2			1 to 6			6	6	35
8.	7	2	4	3	1	4			1, 2, 3			3	3	40
9.	6½	2	3		14	4			1 to 5			5	5	40
10.	7	2, 3			1	3			1 to 5			5	5	55
11.	6	2, 3	4		1	4	1		2 to 5		1	4	5	40
12.	7	1, 2, 3			4	4			1 to 4			4	4	38
13.	7	1, 3			2	3			1 to 4			4	4	40
14.	7	1	3		24	4			1 to 4			4	4	35
15.	7	1, 3	4		25	5			1 to 4			4	4	40
16.	7	2	3		1	3		2	1 to 6		1	5	6	40
17.	7	1, 2			3	3	1		2, 3		1	2	3	42
18.	6	1	2			2		21		2 to 7	1	6	7	42
19.	7	1	2		3	3			1 to 5			5	5	40
20.	6	1	3		24	4	1		2 to 5		1	4	5	40
21.	6	2, 3	4		1	4			1 to 5			5	5	38
22.	6	2	3		21	3	1		2 to 6		1	5	6	40
23.	7	2	3		1	3			1 to 7			7	7	55
24.	7	2			1	2		2	1 to 6		1	5	6	50
25.	7½	2, 3			1	3		2	1, 3 to 6		1	5	6	40
26.	6	2, 3			1	3			1, 3 to 4			4	4	40
Farms using, per cent.		100	53.8	3.8	96.2		19.2	15.4	96.1	3.8	34.6			
Average.	6.7					3.3						4.7	5.0	41.5

a Plank drag.

The tillage practices with corn, which is the only intertilled crop, are very uniform. Practically all the corn land is broken in the spring with 3 or 4 horse sulky plows. The common practice of preparation is to roll the land just after plowing and to follow the roller with a spring-tooth harrow. Then before planting, it is harrowed again with a spike-tooth harrow. Practically all the corn is planted level and in checks $3\frac{3}{4}$ feet apart each way, alternating the hills with two and three grains.

After the corn is up a few of the farmers use the spike-tooth harrow for the first working, but practically all the cultivating is done with a 2-horse 6-shovel cultivator, alternating the cultivations with the rows and across the rows with the checks. Usually five cultivations are given. Both the white and yellow dent varieties of corn are grown.

The most prevalent weeds are foxtail, pigweed, Canada thistle, ragweed, and curled dock.

SURVEYS IN MAURY COUNTY, TENN.

The tillage records (Table XVI) for Maury County, Tenn., were taken near Columbia. This section is rolling and in some parts extremely rough and rocky. Considerable quantities of phosphate rock are mined near Columbia, and limestone is plentiful. The Hagerstown loam, the predominating soil in this vicinity, is very productive.

Most of the farms through the more prosperous sections are rather large, with extensive fields, and are generally operated by the owners with hired labor or tenants. The principal roads have been macadamized and the country generally is prosperous.

Few farms have any set rotations, but a rotation of corn one year, oats one year, wheat one or two years, clover one year, and pasture one year is maintained to some extent. Very little fruit or truck is grown, and the principal sources of income are grain, hogs, and cattle.

The extensive type of farming found here, together with the cheap labor available, is responsible for the irregular methods of corn cultivation. Before planting, the land is usually harrowed twice with a disk harrow and once with a spike-tooth harrow. Most of the corn is planted level and in drills.

After the corn is up it is usually harrowed with a spike-tooth harrow. After this, most of the cultivating is done with a 2-horse 4-shovel cultivator and a 1-horse spike-tooth cultivator. Usually four or five cultivations are given. Crimson clover and rye are frequently sown at the last cultivation as a cover crop. Both the yellow and white varieties of dent corn are grown.

TABLE XVI.—*Tillage practices with corn in Maury County, Tenn., showing depth of plowing, implements used in order of use, number of times each is used, and normal yield of the crop.*

[In columns 3 to 6 and 8 to 17 the figures show the order in which the implement was used on the several farms; as, 1 = first working or cultivation, 2 = second working or cultivation, etc.]

Farm No.	Depth of plowing (inches).	Tillage after plowing and before planting.					Tillage after planting.													Normal yield per acre (bushels).	
		Harrow.			All workings.	Spike-tooth harrow.	Weeder.	1-horse 1-shovel plow.	Cultivator.								Total cultivations.				
		Disk.	Spike-tooth.	Acme.					Roller.	2-horse disk.	3-horse 2-row.	2-horse 4-shovel.	1-horse spike-tooth.	1-horse 2-shovel.	2-horse 8-shovel.	Harrow, weeder, or roller.	Other implements.	All workings.			
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	
1.....	9	1,2	3			3	1	3					2,4	5,6,7			2	5	7	50	
2.....	7	1,2				2	1,3,4		2				5,6,7	3,5			3	5	6	38	
3.....	7	1	2			2			4	1	2		3,5	6				6	6	50	
4.....	8	1				1	1						2,3,4	5			1	4	5	30	
5.....	8	1,2				3	1						2	3 to 6				1	5	6	40
6.....	7	1,2	3			3	1						4,5,6	2,3			1	5	6	36	
7.....	10	1,2		3		3	1,2						3,5,6,7	4			2	5	7	40	
8.....	6	1	2			2	1						2,3	4,5,6		4,5	1	4	5	40	
9.....	7	1	2			2	1						2,3	4,5			1	4	5	40	
10.....	7	1,2	3			3	1					2,3		4			1	3	4	35	
11.....	6	1,2	3			3	1						2,3	4,5			1	4	5	50	
12.....	7	1,2	3			3	a 1		2				3,4,5				1	4	5	50	
13.....	8	1,2	3,4		5,6	6							1	2 to 5				5	5	40	
14.....	7	1	2			2							1 to 4					4	4	50	
15.....	12	1 to 4				4			1					2,3				3	3	25	
Farms using, per cent.		100	66.7	6.7	6.7		73.4	6.7	26.7	6.7	6.7	6.7	73.4	80.0	13.4	6.7	73.4				
Average.	7.7					2.7												4.4	5.4	40.9	

a Roller.

The principal weeds found in this section are crab-grass, smart-weed, cocklebur, pigweed, morning-glory, and thistles.

SURVEYS IN HARTFORD COUNTY, CONN.

The tillage records for Hartford County, Conn., were taken around Hartford, South Manchester, and throughout the Connecticut Valley region, where we find mostly tobacco farms. Enough truck and dairy farms are operated to supply the local market, but the principal sources of farm income are tobacco and fruit.

The country generally is level or gently rolling and the soil is very fertile. (Table XVII.) Practically all the farms are worked by the owners. Most of the farmers have good homes, with unusually good barns and outbuildings. All the principal roads have been macadamized. Good schools are maintained and the country is exceptionally prosperous.

The soil is mostly of a sandy-loam type with a sandy-loam subsoil. The low lands contain more clay. The land is so rolling that tile drains are not usually necessary.

TABLE XVII.—*Tillage practices with corn in Hartford County, Conn., showing depth of plowing, implements used in order of use, number of times each is used, and normal yield of the crop.*

[In columns 3 to 6 and 8 to 14 the figures show the order in which the implement was used on the several farms; as, 1 = first working or cultivation, 2 = second working or cultivation, etc.]

Farm No.	Depth of plowing (inches).	Tillage after plowing and before planting.					Tillage after planting.											Normal yield per acre. ^a
		Harrow.					Spike-tooth harrow.	Weeder.	Cultivator.					Total cultivations.				
		Acme.	Disk.	Spike-tooth.	Plank drag.	All workings.			1-horse. Once to row.		2-horse.			Harrow, weeder, or roller.	Other imple- ments.	All workings.		
									Spike- tooth.	5-shovel.	8-shovel.	6-shovel.	1-row with scraper.					
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	
1	6		1, 2	3		3					1				1	1	40	
2	7		1, 2			2	1	2			3, 4, 5			2	3	5	45	
3	8	2	1			2		1, 2			3, 4, 5			2	4	6	40	
4	7	2	1			2	1					2, 3	4	1	3	4	50	
5	10	1, 2	3					1, 2, 3				4, 5		3	2	5	T 20	
6	8	1	2	3		3		1, 2		3		4, 5		2	3	5	T 15	
7	7		1, 2	3		3		1, 2						4	2	2	50	
8	7			1, 2	3	3				3, 4	1, 2					4	40	
9	9	1, 2		3	3	3			1	2, 3				4	1	3	20	
10	7 ¹ / ₂		1, 2	3		3				1, 2						2	40	
11	7	1				2				1 to 4						4	17	
12	7		1, 2	3		3		1		2, 3				4	1	3	37	
13	6		1	2		2				1			2, 3		3	3	45	
14	8	1	2			2				1, 2				3		3	T 17	
15	6		2	1		2			1 to 4				5		5	5	40	
16	7			1, 2		2			1, 2				3, 4		4	4	33	
17	7	1		2		2	1, 2			3, 4			5, 6	2	4	6	50	
18	8		1	2		2				1, 2, 3					3	3	45	
19	7		1	2		2	1			2, 3				1	2	3	30	
20	7	1		2		2			1			2, 3			1	2	T 12	
21	8		1, 2	3		3		1, 2			3, 4				2	2	60	
22	7		1	2		2			1, 2, 3					4		4	33	
23	8		1, 2			2	1	2						3	2	1	35	
24	8		1, 2	3		3			1, 2					3		3	37	
25	7			1, 2	3	3			1, 2				3, 4		4	4	50	
Farms using, per cent.....		36	76	72	8		20	40	48	16	24	16	56	52				
Average.....	7.4					2.4									3	3.8	39.9	

^a Yields are given in bushels except those marked "T," which are tons of ensilage.

No general rotation is practiced and tobacco is often grown on the same land for 20 years without a change. Usually enough corn and hay is grown to supply home demands. A large part of the corn is grown on sod land. Most of the breaking is done in the spring with a 2-horse plow. This land is very easy to get into good condition. After plowing, the land is usually harrowed once or twice with a disk or acme harrow and then once with a spike-tooth harrow.

Practically all the corn is planted level and mostly in drills $3\frac{1}{2}$ feet apart, with hills 2 or 3 feet apart in the drill and three or four stalks per hill. Chiefly the yellow flint varieties of corn are grown.

After planting, either a spike-tooth harrow or weeder is frequently used for the first cultivation. The 1-horse spike-tooth (fig. 29) and the 1-horse 5-shovel cultivators are extensively used. The 2-horse 8-shovel and 6-shovel cultivators are also considerably used.

A special 2-horse cultivator, equipped with sharp scrapers or knives for cutting the weeds and stirring the surface of the soil, is largely used (fig. 30). This cultivator was designed for culti-

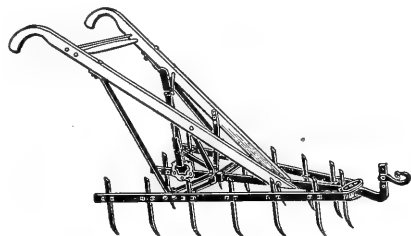


FIG. 29.—A 1-horse spike-tooth cultivator.

vating tobacco, and the knives are so adjusted that they will extend under the leaves and cultivate near the stalk without breaking or bruising the leaves. As shown in Table XVII there is little uniformity in the cultivation methods in this section.

Practically no cover crops are grown, and the supply of organic

matter is largely maintained by stable manure secured from the cities. Immense quantities of commercial fertilizers are used for corn and tobacco, and about 15 tons of stable manure per acre are applied to the tobacco land every other year. Very little stable manure is applied to the corn land, however.

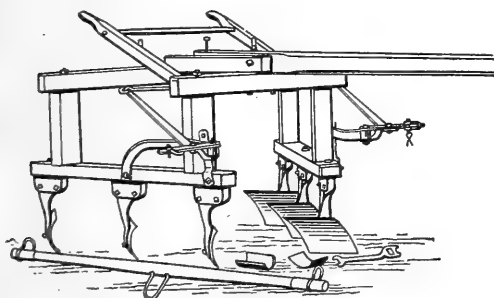


FIG. 30.—A 2-horse cultivator with scraper instead of shovels, used in cornfields in Hartford County, Conn., and in the potato sections of New Jersey.

The most prevalent weeds are ragweed, chickweed, pigweed, smartweed, wild carrot, and barnyard grass.

SURVEYS IN BRADFORD COUNTY, PA.

The tillage records for Bradford County, Pa. (Table XVIII), were taken near Towanda, in the Volusia silt-loam area, which covers a large part of northern Pennsylvania, northeastern Ohio, and southern New York. The soils of this region are naturally divided into two main groups, upland or hill soils and the bottom-land soils. The hill or upland soils are extremely rough and rolling and are not usually very productive. The bottom-land soils are level and very fertile.

None of the upland and only a small percentage of the bottom land is tile drained. A few of the leading valley roads have been macadamized. The valley farms usually have good buildings and show signs of prosperity, but the hill farms are not so productive. But few tenants are found in this section.

TABLE XVIII.—*Tillage practices with corn in Bradford County, Pa., showing depth of plowing, implements used in order of use, number of times each is used, and normal yield of the crop.*

[In columns 3 to 6 and 8 to 13 the figures show the order in which the implement was used on the several farms; as, 1 = first working or cultivation, 2 = second working or cultivation, etc.]

Farm No.	Depth of plowing (inches).	Tillage after plowing and before planting.					Tillage after planting.										Normal yield per acre. ^a
		Harrow.			Roller.	All workings.	Weeder.	Cultivator.						Total culti- vations.			
		Spring-tooth.	Disk.	Spike-tooth.				2-horse 8-shovel.	2-horse 6-shovel.	1-horse 5-shovel, once to row.	1-horse 2-shovel.	2-horse 1 row, with scraper.	Harrow, weeder, or roller.	Other implements.	All workings.		
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	
1.....	7	1,2				2		1,2,3						3	3	50	
2.....	6	1,2				2				1 to 5				5	5	25	
3.....	5	1	2			2				1 to 6				6	6	T 10	
4.....	6	1,2,3		4		4			1 to 5					5	5	T 8	
5.....	7	1,2,3				3			2 to 5					5	5	25	
6.....	7	1,2,3				3				1	2	3		3	3	40	
7.....	6	1 to 4				4	b 1			2 to 5			1	3	4	50	
8.....	6	1,2,3				3		1,2,3						3	3	T 7	
9.....	7	1		2		2				1 to 4		5		5	5	25	
10.....	6	1,2,3		5	c 4	5		1 to 5			6			6	6	40	
11.....	7	1,2,3				3				1,2,3				3	3	T 12	
12.....	6	1,2				3				1 to 6				6	6	40	
13.....	6	1				1				1 to 8				8	8	40	
14.....	5	1,2,3				3				1 to 4				4	4	40	
15.....	6	1 to 4				4				1 to 7				7	7	40	
16.....	7	1,2,3				3			1 to 5					5	5	T 12	
17.....	8	1,2,3				3				1 to 6				6	6	T 10	
18.....	7	1		2		2			1 to 4	5				5	5	50	
19.....	7	1		2		2		1,2						2	2	25	
20.....	4	1,2				2				1,2				2	2	30	
21.....	8	1				1	1,2,3						3	1	4	T 12	
22.....	3	1,2				2				1,2,3				3	3	30	
23.....	6	1,2		3		3			2,3	1				3	3	50	
24.....	5	1		2		2				1,2,3				3	3	35	
25.....	5	1				1				1,2,3						37	
26.....	6	1,3,4			2	4	1		2,3,4				1	3	4	50	
27.....	7	1				1			1 to 4					4	4	40	
28.....	6	1		2		2	b 1		2,3,4				1	3	4	40	
Farms using, per cent.....		100	3.6	28.6	7.1		14.3	7.1	35.7	67.9	7.1	7.1	14.3				
Average.....	6.1					2.5								4.2	4.4	38.2	

^a Yields are given in bushels except those marked "T," which are tons of ensilage.

^b Spike-tooth harrow.

^c Plank drag.

As a general rule the farmers have no set rotation. A rotation of corn or buckwheat one year, oats or wheat one year, and hay two or three years is somewhat practiced. On a few of the bottom farms tobacco is extensively grown. Enough dairy farms are maintained

to supply local demands. A few apples are produced, and most farmers are engaged in general farming.

A large percentage of the upland is in pasture and a considerable number of cattle are produced. Practically all the corn is grown on sod land. Most of the breaking is done in the spring with a 2-horse plow, and this is followed with the spring-tooth and spike-tooth harrows. Because the land is very stony only a few disk harrows are used.

Most of the upland farmers plant corn in drills 3 to $3\frac{1}{2}$ feet apart, with one stalk every 8 inches in the drill, but in the valleys and on level uplands corn is usually planted in checks 3 to $3\frac{1}{2}$ feet apart each way, with three and four stalks to the hill. In either case the planting is level.

After planting, a few of the farmers use a spike-tooth harrow or weeder for the first cultivation, but most of the cultivating is done with either a 2-horse 6-shovel cultivator or a 1-horse 5-shovel cultivator, the 5-shovel cultivator being largely used. Occasionally a 2-horse 8-shovel cultivator and a 1-horse 2-shovel cultivator are found. On the tobacco farms a special cultivator similar to that used in the Connecticut Valley tobacco district is used. This is a 2-horse cultivator equipped with scrapers or knives for stirring only the surface soil and cutting the weeds. It is so adjusted that the knives extend under the tobacco leaves and cultivate near the stalk without breaking or bruising the leaves. Few cover crops are grown, and corn land is usually seeded to oats in the spring.

Both the flint and dent varieties of corn are grown, but the dent is largely used for ensilage.

The most prevalent weeds are ragweed, smartweed, pigweed, and wild carrot.

SURVEYS IN CHRISTIAN COUNTY, KY.

Most of the tillage records for Kentucky (Table XIX) were taken in southern Christian County, in the section around Pembroke. This is a level prairielike section with very fertile soil of a silt-loam type. This soil has good natural drainage, and ordinarily no tiles or surface drains are found.

Practically all the leading roads have been macadamized. The farmers have exceptionally good houses and appear prosperous. Mostly negro labor is employed on the farms, which are large, but since cheap labor is available very little improved machinery is employed.

A general rotation of corn or tobacco one year, wheat two years, and hay two years is maintained to some extent on most farms. Cow-peas are grown for hay in this section and as a catch crop are often sown in corn at the last cultivation.

The principal farm incomes are from wheat, hay, tobacco, and hogs. Most of the corn is fed on the farm. Very little fruit or truck is grown except for the local market.

TABLE XIX.—*Tillage practices with corn in Christian County, Ky., showing depth of plowing, implements used in order of use, number of times each is used, and normal yield of the crop.*

[In columns 3 to 5 and 7 to 12 the figures show the order in which the implement was used on the several farms; as, 1 = first working or cultivation, 2 = second working or cultivation, etc.]

Farm No.	Depth of plowing (inches).	Tillage after plowing and before planting.				Tillage after planting.									Normal yield per acre (bushels).
		Harrow.			All workings.	Spike-tooth harrow.	Cultivator.				1-horse turning plow, twice to row.	Total cultivations.			
		Disk.	Spike-tooth.	Roller.			1-horse spike-tooth, once to row.	2-horse, 1-row, 4-shovel.	2-horse, 1-row, 8-shovel.	1-horse, 2-shovel, twice to row.		Harrow, weeder, or roller.	Other implements.	All workings.	
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1	9	1,2	3,4		4	1			2,3,4			1	3	4	20
2	7	1,2	3		3	1	4,5,6		2,3			1	5	6	25
3	7	1			1	1	2,3,4					1	3	4	40
4	6	1	2		2		3,4			1,2			4	4	35
5	8	1,2	3		3		1 to 4						4	4	40
6	8	1,2	3		3	1,2	3 to 7					2	5	7	50
7	7	1,2	3		3	1	4 to 7				2,3	1	6	7	40
8	7	1,2	3		3	1				2 to 5		1	4	5	40
9	8	1,2	3		3	1	4				2,3	1	3	4	40
10	8	1,2	4	3	4		3,4	1,2					4	4	40
11	6	1 to 4	5		5			1 to 4					4	4	40
12	6½	1,2	3		3	1	6			2 to 5		1	5	6	40
13	4	1 to 4	5		5	1,2		3,4				2	2	4	35
14	8	1,2	3		3	1	2 to 5					1	4	5	30
15	7	1			1	1		2,3,4				1	3	4	40
16	7	1,2	3		3	1,2	8		7	3 to 6		2	6	8	30
17	7	1	2		2	1		2,3,4				1	3	4	40
18	6	1,2	3		3	1				2,3,4		1	3	4	35
19	12	1,2,3			3					1,2,3,4			7	3	35
20	7	1			1		5,6,7			3,4	1,2		7	7	40
21	6	1	2		2	1	4,5			2,3		1	4	5	30
22	6	1,2			2	1	2 to 6					1	5	6	30
23	6	1,2	3		3	1	4 to 7				2,3	1	6	7	50
24	8	1,2,3	4	5	5		1 to 5						5	5	40
25	7	1,2	4	3	4		5,6				1 to 4		6	6	40
26	7	1	3	2	3	a 1	2 to 6					1	5	6	35
Farms using, per cent.		100	80.7	15.4		69.2	69.2	19.2	11.5	34.6	15.4	69.2			
Average	7.1				3								4.3	5.1	36.9

a Roller.

This region combines the desirable conditions of the level prairie lands of the corn belt with the cheap labor conditions of the cotton belt, and the tillage methods employed here combine the practices of both sections. Corn is generally grown on sod land. Usually as much plowing is done in the fall as time and the weather will permit, and the remainder is plowed in the spring. A few farmers plow in the fall and then rebreak the land in the spring. After plowing, the land is usually harrowed twice with a disk and once

with a spike-tooth harrow. When the land is cloddy the roller is sometimes used.

Most of the corn is planted with a 2-horse 2-row planter. Some farmers plant by hand when labor is plentiful, and a few use a 1-horse planter. Seventy-three per cent of the planting is in checks from $3\frac{1}{2}$ to 4 feet apart each way, with two stalks per hill. Practically all the corn is planted level. After the corn is up it is usually harrowed with the spike-tooth harrow. After this most of the cultivating is done with a 1-horse spike-tooth cultivator and a 1-horse 2-shovel cultivator (fig. 31).

Often a 1-horse turning plow is used as a cultivator, first to plow the dirt away from the corn, which is known as barring-off, then the middles are plowed out, throwing dirt to the corn. The 2-horse 4-shovel (fig. 32) and 8-shovel cultivators are used, but not so much as the 1-horse implements. Principally because of cheap labor, the

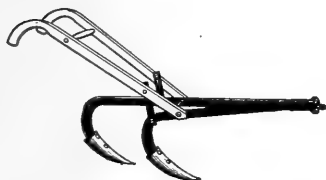


FIG. 31.—A 1-horse 2-shovel cultivator, a tillage implement in general use in cornfields in the South.

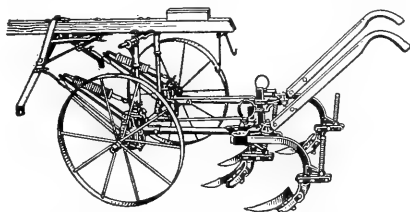


FIG. 32.—A 2-horse 4-shovel corn cultivator.

1-horse implements are largely used, and only where more expensive labor is employed is much labor-saving machinery found.

Practically no cover crops are grown. The white dent varieties of corn are principally grown. The most prevalent weeds are crabgrass, smartweed, ragweed, and wild onion.

SURVEYS IN HAMILTON COUNTY, NEBR.

Hamilton County is in the prairie section of Nebraska and practically all the land is in cultivation. The soil in this region is very fertile, but seasons are often unfavorable and crop production varies largely with the amount of rainfall. The soil is a deep black silt loam with a clay subsoil. It becomes very hard in dry weather and frequently cracks open. In the northern part of the county along the Platte River the soil is more sandy and not so productive as the silt-loam type.

This is a comparatively level region, just rolling enough to give good natural drainage and not steep enough to cause erosion or to interfere with the use of machinery. (Table XX.) There are no tile drains and practically no surface ditches or terraces.

Most of the farms are worked by the owners, and by having large fields and using heavy teams and improved machinery the minimum amount of labor is required. No definite cropping system is maintained, but usually the land is in corn for three or four years, in oats one year, and then wheat for three or four years. Some timothy and clover is grown, but most of the hay is produced from alfalfa, which does well in this region. Bluegrass does well and is often grown for pasture.

TABLE XX.—*Tillage practices with corn in Hamilton County, Nebr., showing depth of plowing, implements used in order of use, number of times each is used, and normal yield of the crop.*

[In columns 3 to 5 and 7 to 9 the figures show the order in which the implement was used on the several farms; as, 1 = first working or cultivation, 2 = second working or cultivation, etc.]

Farm No.	Depth of plowing (inches)	Tillage after plowing and before planting.				Tillage after planting.						Normal yield per acre (bushels).
		Harrow.		Roller.	All workings.	Spike-tooth harrow.	Roller.	2-horse 6-shovel cultivator.	Total cultivations.			
		Spike-tooth.	Disk.						Harrow, weeder, or roller.	Other implements.	All workings.	
1	2	3	4	5	6	7	8	9	10	11	12	13
1.....	6	1,3	2	.....	3	1	.....	2 to 5	1	4	5	40
2.....	5	2	1	.....	2	1	.....	2,3,4	1	3	4	30
3.....	5	1,3	2	.....	3	1,2	.....	3,4,5	2	3	5	30
4.....	7	1,3	2	.....	3	1	.....	2,3,4	1	3	4	35
5.....	5	1	2	.....	2	1	.....	2,3,4	1	3	4	33
6.....	6	1,3	2	.....	3	1,2	.....	3 to 6	2	4	6	40
7.....	6	1,3	2	.....	3	1,2	.....	3,4,5	2	3	5	45
8.....	6	1,3	2	.....	3	1,2,3	.....	4 to 7	3	4	7	45
9.....	5	1	2	.....	2	1,2	.....	3,4,5	2	3	5	20
10.....	5	1,2	.....	2	2	1	.....	2,3,4	1	3	4	40
11.....	7	1,3	2	.....	3	1,2	.....	3 to 6	2	4	6	35
12.....	5	.....	1,2	.....	2	1,2	.....	3 to 6	2	4	6	45
13.....	6	1	2	.....	2	1	.....	2,3,4	1	3	4	30
14.....	7	1,3	.....	2	3	1	.....	2,3,4	1	3	4	40
15.....	6½	1	.....	.....	1	1,2	.....	3,4,5	2	3	5	30
16.....	5½	1,3	2	.....	3	1,2	.....	3 to 6	2	4	6	40
17.....	5	1	.....	.....	1	1	2	3 to 6	2	4	6	30
18.....	7	2,3	1	.....	3	1	.....	2,3,4	1	3	4	30
19.....	6	1,3	2	.....	3	1	.....	2 to 5	1	4	5	35
20.....	6	2	1	.....	2	1,2	.....	3 to 6	2	4	6	30
21.....	5	1,3	2	.....	3	1,2	.....	3,4,5	2	3	5	30
22.....	5	1,3	2	.....	3	1,2	.....	3,4,5	2	3	5	40
23.....	6	1,3,4	2	.....	4	1,2	.....	3 to 6	2	4	6	35
24.....	6	2	1	.....	2	1,2,3	.....	4,5,6	3	3	6	35
25.....	6	1	2	.....	2	1	.....	2 to 5	1	4	5	32
Farms using . . . per cent.	.....	96	84	4	.....	100	4	100	100	.....	.....	.....
Average.....	5.8	.....	.....	.....	2.5	.....	.....	.....	.....	3.4	5.1	35

A considerable number of cattle and usually from 75 to 100 hogs are kept on a farm. Practically no fruit or truck is produced, and the farm incomes are largely from hogs, grain, hay, and cattle.

The tillage practices with corn are very uniform. Usually the land is disked before plowing, which cuts up the stalks and puts the land in better condition. Practically all the plowing is done with a

4-horse gang plow (fig. 33) or a sulky disk plow (fig. 34) and the land is gone over immediately with a spike-tooth harrow. Then before planting, it is harrowed with the disk and again with the spike-tooth harrow.

Practically all the planting is done with a 2-horse 2-row planter, and the corn is planted level in checks $3\frac{1}{2}$ feet apart each way, alternating the hills with two and three grains. After the corn is up, it is harrowed once or twice with a spike-tooth harrow and then cultivated three or four times in alternate directions with a 2-horse 6-shovel cultivator.

No cover crops are grown. The stable manure is largely applied to wheat, and no commercial fertilizer is used for corn.

Both the white and yellow dent varieties of corn are grown. The most prevalent weeds are foxtail, bindweed, smartweed, and pigweed.

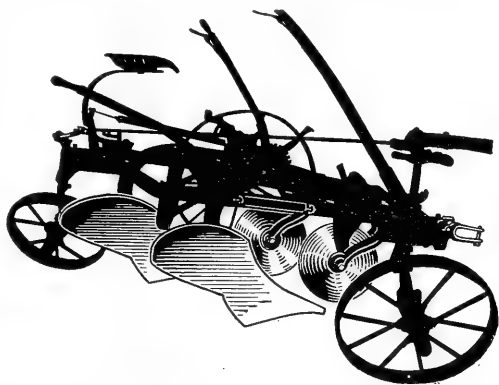


FIG. 33.—A gang plow for four or five horses, extensively used in the Central West for breaking land.

SURVEYS IN ROCKWALL AND GRAYSON COUNTIES, TEX.

The tillage records for Texas (Table XXI) were taken in Grayson County around Sherman and in Rockwall County near Fate. The soil in these regions is of the black clay-loam type and very fertile.

The land is rolling and no tile drains are necessary. Only a few surface ditches are required.

A few of the roads have been macadamized and others are being improved. The farms have exceptionally good houses and outbuildings, and fair schools are maintained. A considerable portion of the land is worked by tenants, but usually under the supervision of the owner.

The fields are large, and 4 or 5 horse teams are commonly used. A few farmers find the traction engine economical.

The seasons are rather uncertain, and crop yields depend largely on the amount of rainfall. No general rotation is practiced, but usually corn and cotton follow small grain. Frequently cotton is grown on the same land two years in succession and then is followed

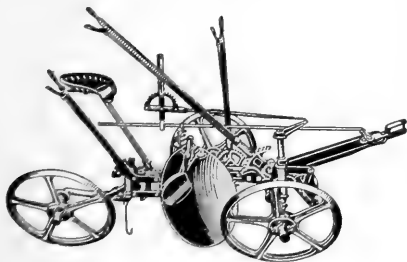


FIG. 34.—A sulky disk plow.

by corn. Oats and wheat are not usually grown on the same land for two succeeding years, but oats are often grown one year and wheat the next. Some fruit and truck is grown. Few cattle or hogs are kept, and the principal farm incomes are from cotton and grain. Alfalfa is grown on some of the bottom lands and does well except in dry seasons.

TABLE XXI.—*Tillage practices with corn in Rockwall and Grayson Counties, Tex., showing depth of plowing, implements used in order of use, number of times each is used, and normal yield of the crop.*

[In columns 4 to 7 and 9 to 11 the figures show the order in which the implement was used on the several farms; as, 1 = first working or cultivation, 2 = second working or cultivation, etc.]

Farm No.	Depth of plowing (inches).	Tillage after plowing and before planting.						Tillage after planting.						Normal yield per acre (bushels).
		Bedded as broken.	Harrow.		Rows run with lister.	Rebedded with turning plow.	All workings.	Spike-tooth harrow.	Cultivator.		Total cultivation.			
			Spike-tooth.	Disk.					2-horse 4-shovel.	2-horse 4-shovel, with sweeps.	Harrow, weeder, or roller.	Other imple-ments.	All workings.	
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1.....	8	1	.....	1	a 2	.....	2	1, 2	3, 4	5, 6	2	4	6	37
2.....	4	1	1	.....	.....	.....	1	.....	1, 2	3	.....	3	3	30
3.....	4	1	.....	.....	a 1	.....	1	.....	.....	1, 2, 3	.....	3	3	25
4.....	4	1	.....	.....	.....	.....	.....	.....	1, 2, 3	4	.....	4	4	40
5.....	8	1	.....	.....	a 1	.....	1	.....	1	2, 3	.....	3	3	30
6.....	8	1	.....	.....	a 1	.....	1	.....	1, 2, 3	.....	.....	3	3	30
7.....	7	1	.....	.....	.....	1	1	.....	1, 2	3, 4	.....	4	4	30
8.....	8	.....	.....	.....	a 2	.....	2	.....	1, 2, 3	.....	.....	3	3	29
9.....	6	.....	1, 2	.....	.....	.....	2	.....	1, 2	3, 4	.....	4	4	40
10.....	7	.....	1	.....	.....	.....	1	.....	1, 2, 3	.....	.....	3	3	50
11.....	7	1	2	.....	1	.....	2	.....	1	2, 3	.....	3	3	25
12.....	6	.....	1	.....	2	.....	2	.....	1, 2	3, 4	.....	4	4	30
13.....	4	.....	1	.....	2	.....	2	1, 2	3, 4, 5	.....	2	3	5	40
14.....	8	.....	1	.....	2	.....	2	.....	1, 2	.....	.....	5	5	40
15.....	4	.....	1	.....	.....	.....	1	.....	1, 2, 3	.....	.....	3	3	20
16.....	5	.....	1	.....	2	.....	2	.....	1	2, 3, 4	.....	4	4	35
17.....	5	.....	1, 2, 3	.....	4	.....	4	1, 2, 3	.....	4, 5, 6	3	3	6	30
18.....	4	.....	1, 2	.....	.....	.....	2	.....	.....	2 to 5	.....	4	5	30
19.....	6	.....	1, 2	.....	.....	.....	2	1	.....	2, 5	1	4	5	30
20.....	8	.....	1	.....	2	.....	2	.....	1, 2	3, 4, 5	.....	5	5	40
21.....	8	.....	1	.....	.....	.....	2	.....	1, 2	3	.....	3	3	40
22.....	8	.....	1, 2	.....	.....	.....	2	1	2, 3	4	1	3	4	35
23.....	1½	1	1	.....	.....	.....	1	.....	1	2, 3, 4	.....	4	4	50
23.....	1½	1	.....	.....	.....	.....	.....	.....	.....	1, 2, 3	.....	3	3	35
24.....	5	1	.....	.....	1	.....	1	.....	.....	1, 2, 3	.....	3	3	25
Farms using, per cent.....	41.6	66.7	4.2	54.2	4.2	.....	20.8	70.8	87.5	20.8	.....	3.5	3.9	33.6
Average.....	6.4	.....	.....	.....	.....	.....	1.5	.....	.....	.....	.....	.....	.....	.....

a Lister and planter combined.

The tillage practices with corn are rather unusual. A large part of the land is broken in the fall with a 4-horse lister, or middle buster, which leaves the land in ridges the width apart the corn rows are to be. This implement (fig. 4) plows out a furrow by throwing the dirt to both sides. After ridging the land in the fall it is allowed to stand until spring without further preparation. Before planting, the ridges are usually harrowed with a spike-tooth harrow. Then

in planting a 2-horse 1-row planter is used. This planter is equipped with sweeps or a broad shovel, which tears down this ridge and makes a furrow where the ridge stood, in which the corn is planted several inches below the surface level. Practically all the corn is planted in drills $3\frac{1}{2}$ feet apart with one stalk every 20 inches. Some farmers break the land level with 4-horse gangs, harrow with a spike-tooth harrow, and then lay off the rows with a lister and plant the corn in the bottom of this furrow about 4 inches below the surface level. In some of the bottoms where drainage is poor corn is planted on beds. On some of the higher lands which are inclined to be dry the land is bedded and corn planted in the water furrow between the beds.

After the corn is up, a few farmers use a spike-tooth harrow for the first cultivation, and after this practically all the cultivating is done with a 2-horse 4-shovel cultivator, using either 4-inch shovels or sweeps. For the first workings the shovels are mostly used, especially next to the corn, but sweeps may be used for the middle. At the last cultivation sweeps are mostly used and are set so that the land is leveled by the last cultivation.

The yellow dent varieties of corn are principally grown. Little commercial fertilizer is used and stable manure is not considered very valuable; it is often burned.

The most prevalent weeds are Johnson grass, Bermuda grass, pig-weed, cocklebur, and nut-grass.

SURVEYS IN SCOTLAND COUNTY, N. C.

Scotland County, N. C., is a typical cotton region, being very level, with a sandy-loam soil and a clay subsoil. Only on the heavy bottom lands is tiling necessary, nor is much surface ditching required. Some open ditches are found surrounding the fields.

Most of the main roads have been improved, principally with sand and clay. Fairly good schools are maintained. The landowners have exceptionally good houses and the region appears very prosperous.

Practically all the land is owned by white men and worked under the supervision of the owners by negro tenants on a share basis, in which the tenant furnishes the labor and gets one-third the crop. In some cases the tenant furnishes the labor, half the fertilizer, half the seed, and gets half the crop. A negro man and his family, with one horse, usually work about 19 acres of cotton and 6 acres of corn.

No general rotation is practiced in this section. Corn is usually planted on the bottom lands which are too heavy for cotton and on the less fertile uplands. The principal crops grown are cotton, corn, oats, and cantaloupes. By far the most important crop is cotton, and the acreage in cotton is limited only by the labor available for picking.

TABLE XXII.—*Tillage practices with corn in Scotland County, N. C., showing depth of plowing, implements used in order of use, number of times each is used, and normal yield of the crop.*

[In columns 4 to 11 and 13 to 19 the figures show the order in which the implement was used on the several farms; as, 1 = first working or cultivation, 2 = second working or cultivation, etc.]

Farm No.	Depth of plowing (inches).	Tillage after plowing and before planting.										Tillage after planting.										Normal yield per acre (bushels).	
		Bedded as broken.	Harrow.		Bedded with—			1-horse.		1-horse plow.		2-horse disk harrow.		Fertilizer distributor.		1-horse cultivator.		Total cultivations.					
			Disk.	Spike-tooth.	Turning plow.	2-horse.	2-horse lister.	1-shovel plow.	2-shovel.	Spike-tooth.	All workings.	1-shovel.	Turning.	15	16	17	18	19	20	21	22		
1	7	1	1					2			3	3	1	2		1, 2		1 to 4			4	4	40
2	6½	1						1			2	2	1	2, 5		3, 4	3, 4, 6, 7				2	2	20
3	8							1			3	3	1	1, 4		3	2 to 5				5	5	38
4	8			1				2				2	3	3							3	3	40
5	6				1			2			3	3	1, 2	3		4	4, 5				5	5	50
6	6	1						3			2	2	1, 2	3		2	2 to 6				5	5	20
7	6		1					3			3	3	1	1		2	4				6	6	40
8	7			1	2			3			3	3				2	2 to 6				4	4	25
9	4	1	1			2		1			1	1				1	1 to 4				4	4	35
10	7						2				2	2		1, 3		3	2, 4				4	4	45
11	4	1						1			1	1		1, 3		2	2, 4				4	4	15
12	8					1		2			3	3	2	1, 3		3	3, 4				4	4	25
13	9				1			4				4	1	4		2	2, 3, 5				5	5	30
14	9		2	1				4			4	4	1, 2	3		2	2 to 5		1				
15	6	1						2			2	2	1, 2	3		2					3	3	40
16	5	1						3			4	4	1			2, 5	2 to 5				5	5	20
17	8			1	2			3			4	4	1			2	2 to 5				3	3	40
18	8		1, 2		3			4			4	4	1	2		2	2, 3, 4				5	5	28
19	14			1				3			4	4	2	2		2	2, 3, 4		3		2	2	40
20	12		1, 2			2		4			4	4	1, 4	2		4	3, 5, 6, 7				7	7	40
21	6	1					1				4	4		2		2	1 to 5				5	5	40
22	8							1			2	2		1, 3		2	2, 4				4	4	50
23	8		1			2		2				3	1, 2			2	1 to 4				3	3	40

[illegible]

a Spike-tooth harrow.

Cantaloupes are largely grown, and at the last cultivation cowpeas are sown broadcast over the entire field, furnishing shade for the ripening melons. Later, crab-grass comes up among the pea vines, and the mixture makes excellent hay. Practically no fruit is grown and only enough truck crops other than cantaloupes are grown to supply local demands.

Most of the cultivated land is in intertilled crops, labor being plentiful during the cultivation period. The cultivating is done with 1-horse implements (Table XXII). This is because more labor is available than is necessary during the cultivating season, in order that there may be enough available for picking cotton in the fall.

Some time during the winter or spring the cotton and corn stalks are chopped up with a stalk cutter or disk harrow.

Practically all the corn land is broken in the spring, mostly with a 2-horse plow. A few farmers practice breaking in the fall with a 2-horse plow and then rebreak in the spring with a 1-horse plow. It is a common practice to break the land for corn by throwing it up in beds the width the corn rows are to be apart. Occasionally land is broken level and then bedded. After bedding, no further preparation is given until planting time, and for preparation and planting a modified form of the Williamson plan is used. The corn is planted in the water furrow between the beds, but before planting a 1-horse subsoiling plow is run in the bottom of this water furrow, breaking the subsoil to a depth of 6 or 8 inches, and the corn is planted in this furrow by hand or with a 1-horse planter. The planting is always in drills about $5\frac{1}{2}$ feet apart, with hills $1\frac{1}{2}$ feet apart in the drill and one or two stalks to the hill.

Most of the farmers employ a modified form of the Williamson plan of cultivation. After planting, the corn is allowed to stand for three or four weeks before the first cultivation is given, in order to stunt the growth of the young plants. This is supposed to give a larger production of grain with a smaller stalk growth. To further this process no fertilizer is applied at planting time, but after the first cultivation some is applied at each cultivation, and during the season 500 to 700 pounds per acre are applied.

For the first cultivation one furrow is run on either side of the row very close to the corn, with a 4-inch 1-shovel plow going as deep as one mule can pull it. The middle is not plowed out at this cultivation.

Usually for the second cultivation a furrow is opened with a lister directly between the rows; then with a 1-horse turning plow all the middle is plowed out, throwing the dirt to this furrow and away from the corn. This usually takes six furrows with the turning plow.

For the next cultivation the middle is plowed out with the turning plow or sweep, throwing dirt to the corn. After this, practically all

the cultivating is done with sweeps covering all the middle with three furrows, and by the last cultivation the land is comparatively level.

As shown in Table XXII, often two or more implements are used for the same cultivation. Fertilizer is frequently applied to corn at the second or third cultivation, in which case the fertilizer distributor (fig. 35) is run close to the corn row and the middle plowed out with the sweep or 1-horse turning plow.

Very little stable manure is produced. Practically no cover crops are grown, but at the last cultivation cowpeas are often sown broadcast between the corn rows. Frequently peanuts are planted in drills between the corn rows at the last cultivation, and after the corn is gathered the field is pastured with hogs. Most of the corn is of the white dent varieties.

The most prevalent weeds are crab-grass, cocklebur, and smart-weed.

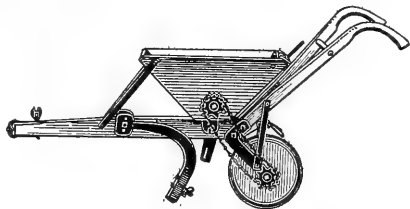


FIG. 35.—A fertilizer distributor.

SURVEYS IN AUGUSTA COUNTY, VA.

Augusta County is located in the Shenandoah Valley, Va., and the soil is of the Hagerstown series. This region is extremely rolling and in some places rocky, but the farms are divided into large fields, and improved machinery is generally used. (Table XXIII.) The work is mostly done with 2 and 3 horse teams. Except for a few bottoms none of the land is tile drained, but practically all the land is drained by surface ditches to prevent erosion.

Most of the leading roads have been macadamized and are operated under the toll system. The farms are usually operated by the owners with hired labor instead of tenants. The farms are large, and the people generally are in comfortable circumstances.

On most farms a rotation of corn one year, wheat two years, and hay two years is maintained. A large percentage of the land is in pasture, and apples are extensively grown. The farm income is principally from apples and grain, supplemented by hay and cattle.

The corn is grown on pasture or hay sod, and most farmers prefer to plow this land in the spring. Usually the breaking is done level with a 2-horse or 3-horse plow. After breaking, the land is harrowed once or twice with a spring-tooth or disk harrow, and before planting it is gone over with a spike-tooth harrow or roller. The planting is largely done with 2-horse 2-row planters. Corn is usually planted level and in drills $3\frac{1}{2}$ feet apart, with one stalk every 18 inches in the drill. Where the land is not too rolling, the corn is planted in checks $3\frac{1}{2}$ feet apart each way, with two stalks to the hill.

TABLE XXIII.—*Tillage practices with corn in Augusta County, Va., showing depth of plowing, implements used in order of use, number of times each is used, and normal yield of the crop.*

[In columns 3 to 7 and 9 to 14 the figures show the order in which the implement was used on the several farms; as, 1 = first working or cultivation, 2 = second working or cultivation, etc.]

Farm No.	Depth of plowing (inches).	Tillage after plowing and before planting.						Tillage after planting.									Normal yield per acre (bushels).
		Harrow.					All workings.	Spike-tooth harrow.	Cultivator.					Total cultivations.			
		Spring-tooth.	Disk.	Spike-tooth.	Roller.	Log drag.			1-horse.		2-horse.			Harrow, weeder, or roller.	Other implements.	All workings.	
									3-shovel.	2-shovel.	6-shovel.	8-shovel.	10-shovel, spring-tooth.				
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1	9	1, 2, 3						3			1 to 4				4	4	40
2	7	1, 2		3				3			1, 2, 3				3	3	35
3	8	1, 2		3				3			1 to 4				4	4	35
4	6	1, 2	3		4, 5			5			1 to 5				5	5	25
5	10	3	1, 2					3			1, 2					2	40
6	9		1					1			1, 2, 3				3	3	40
7	8	1, 3		2				3	1, 2, 3						3	3	25
8	6	2, 3, 4	1					4	1		2, 3, 4			1	3	4	18
9	9	3	1, 2		4			4	1, 2			3 to 7		2	5	7	50
10	7	1, 2, 3						3			1 to 4				4	4	12½
11	9		1	2	3			3	1		2 to 5			1	4	5	50
12	8		1	2				2	1	2	3, 4, 5			1	4	5	25
13	8		1	2				2	1, 2		3 to 6			2	4	6	30
14	8	1	2, 4			3		4		1, 2	3				3	3	30
15	8	3	1, 2					3	1		2, 3, 4			1	3	4	20
16	9	1	2					2			1, 2, 3				3	3	37
17	8	1						1	1		2, 3, 4			1	3	4	40
18	8	3	1				2	3		1, 2					2	2	40
19	8	1 to 4						4	1 to 5						5	5	16
20	9	3	1, 2					3			1 to 4				4	4	40
21	7	2, 3	1		4			4			1 to 5				5	5	35
22	10	2, 3	1					3	a 1, 2		3 to 6			2	4	6	50
23	5	1	2	3				3	1	4	2, 3			1	3	4	50
24	7		1					1					1 to 4		4	4	30
25	8	3	1		2			3	1		2 to 6			1	5	6	20
26	8	1, 2, 3						3			1 to 4				4	4	30
27	9	1 to 4						4		4	1, 2, 3				4	4	20
28	9	1, 2		3				3			1, 2, 3				3	3	50
Farms using... per cent.		85.5	60.7	28.6	17.8	7.1		35.7	14.3	10.7	78.5	7.1	3.6	35.7			
Average.	8						3.0								3.7	4.1	33.0

a Roller.

After the corn is up, about one-third of the farmers use a spike-tooth harrow for the first cultivation. After this, most of the cultivating is done with a 2-horse 6-shovel cultivator. Usually three or four cultivations are given with this implement. Other cultivators found less frequently are the 2-horse 8-shovel, 1-horse 3-shovel, 1-horse 2-shovel, and 2-horse spring-tooth. Most of the farmers go over the field at least once with a hoe to chop out weeds and to replant.

Scarcely any cover crops are grown, and wheat is usually sown after corn. The yellow dent varieties of corn are largely grown.

The most prevalent weeds are foxtail, lamb's-quarters, chicory, and Spanish needle.

Considerable fertilizer is used for corn and wheat, and stable manure is applied broadcast to the sod land before planting to corn.

SURVEYS IN WAUSHARA COUNTY, WIS.

The tillage records for Wisconsin (Table XXIV) were taken in northwestern Waushara County, principally around Plainfield.

TABLE XXIV.—*Tillage practices with corn in Waushara County, Wis., showing depth of plowing, implements used in order of use, number of times each is used, and normal yield of the crop.*

[In columns 3, 4, and 6 to 11 the figures show the order in which the implement was used on the several farms; as, 1 = first working or cultivation, 2 = second working or cultivation, etc.]

Farm No.	Depth of plowing (inches).	Tillage after plowing and before planting.			Tillage after planting.										Normal yield per acre. ^a
		Harrow.		All workings.	Spike-tooth harrow.	Weeder.	Cultivator.				Total cultivations.				
		Disk.	Spike-tooth.				2-horse.			Harrow, weeder, or roller.	Other implements.	All workings.			
							6-shovel.	8-shovel.	10-shovel spring-tooth.				1-horse 5-shovel, once to row.		
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	
1	5		1	1	1		2, 3, 4				1	3	4	35	
2	4	1	2	2	1		2 to 5				1	4	5	30	
3	5	1	2	2	1	2, 4			3, 5, 6		3	3	6	50	
4	6		2	2	1		4, 5	2, 3			1	4	5	25	
5	6	1, 2	3	3	1, 2	4	3, 5			6	3	3	6	T 8	
6	6	1	2	2	1	3	2, 4, 5				2	3	5	30	
7	6	1	2	2	1, 2	3, 5	4, 6, 7, 8				4	4	8	25	
8	6	1	2	2	1, 2		3 to 6				2	4	6	30	
9	6	1	2	2	1	2	3, 4			5	2	3	5	20	
10	5		1, 2	2	1		3, 4			2	1	3	4	25	
11	6		1	1	1	3, 5	2, 4, 6				3	3	6	25	
12	6		1, 2	2	1	2	3, 4, 5				2	3	5	30	
13	5	1	2	2	1	3	2, 4, 5				2	3	5	35	
14	5		1	1	1, 2		3, 4, 5				2	3	5	30	
15	6	1	2	2	1		2, 3, 4				1	3	4	45	
16	6		1, 2	2	1	2, 3, 4	5, 6, 7				4	3	7	25	
17	5	1	2	2	1, 2			3, 4, 5		6	2	4	6	25	
18	6		1	1		2, 4	1, 3				2	2	4	20	
19	6		1	1	1		2 to 5				1	4	5	35	
20	6	1	2	2	1	3, 5	2, 4, 6, 7				3	4	7	25	
21	5	1	2	2	1	2	3 to 6				2	4	6	40	
22	5½		1	2	1		2 to 5				1	4	5	35	
23	4	1	2	2	1		2, 3, 4				1	3	4	25	
24	6	1	2	2	2		1, 3, 4, 5				1	4	5	35	
25	5	1	2	2	1	3	2, 4, 5				2	3	5	25	
26	6	1	2	2	1	2, 4	3, 5, 6, 7				3	4	7	25	
Farms using . . . per cent.		69.2	100		96.2	53.8	92.3	7.7	3.8	15.4	100				
Average	5½			1.8								3.4	5.4	30.4	

^a Yields are given in bushels except on farm 5, where "T" means tons of ensilage.

This is primarily a potato-growing section, with a sandy or sandy-loam soil 8 to 12 inches deep, underlain with a heavier sandy-loam subsoil, which is often gravelly. This area is almost level, and since the soil is of a sandy character practically no drainage is required except on the low lands, where big drainage ditches are cut every mile or so.

The leading roads have been macadamized, and the country is fairly prosperous. Practically all the farms are worked by their owners, with some hired labor for harvesting crops. The farms range from 150 to 200 acres in size, with 125 to 150 acres tillable, but a considerable part of this area is usually in pasture.

As a general rule no definite rotations are practiced, but usually potatoes are planted on sod land, and corn is either grown on sod land or follows potatoes. Corn is followed by rye or oats, and potatoes, when not followed by corn, are followed with rye or oats. Timothy and clover is often sown with rye and oats. This crop is cut for hay the first year and allowed to stand another year for pasture. Hardly enough fruit or truck is grown to supply home demands, but the muck areas are well adapted to trucking, and cranberries are grown in favorable sections.

The principal sources of income are from potatoes and grain. Enough dairy farms are maintained to supply local demands, and enough hogs are produced to supply meat for the local markets.

The tillage methods are exceptionally uniform in this region. About half the corn land is broken in the fall and half in the spring with 2-horse and 3-horse plows. Then, before planting, the land is harrowed once with a disk and once with a spike-tooth harrow. Practically all the corn is planted level, and about half the planting is in checks $3\frac{1}{2}$ feet apart each way, with two stalks to the hill. About one-half is planted in drills $3\frac{1}{2}$ feet apart, with one stalk every 10 or 12 inches in the drill. Most of the planting is done with a 2-horse 2-row planter, but some farmers in checking plant by hand.

After planting, the field is gone over with a spike-tooth harrow once and with a weeder once. After this most of the cultivating is done with a 2-horse 6-shovel cultivator. The 2-horse 8-shovel, the 2-horse 10-shovel spring-tooth, and the 5-shovel 1-horse cultivators are used by a few farmers. After going over the field twice with the spike-tooth harrow or weeder, usually three cultivations are given.

Practically no cover crops are grown. No commercial fertilizer is used. Stable manure is usually applied to the sod land before breaking for potatoes.

The early white dent varieties of corn are principally grown.

The most prevalent weeds are foxtail, wild buckwheat, ragweed, quack-grass, and pigweed.

SURVEYS IN BATES COUNTY, MO.

Bates County is in the extreme western tier of Missouri and fairly well represents conditions as found in the corn belt of western Missouri and eastern Kansas. It is a typical prairie region, with a clay-loam soil underlain with a heavier loamy clay subsoil. The land is gently rolling, and no drainage is required. The soils of this county are very fertile, and the limiting factor in crop production is the amount of rainfall.

This region is fairly prosperous and has the general western spirit. Most of the leading roads have been improved. Good farmhouses and outbuildings are found, and the country appears prosperous to a greater extent than it really is. With good seasons the farmers get exceptionally good returns, but often the seasons are unfavorable.

About one-third of the farms in this county are operated by tenants, mostly for cash rent. The farms visited average 184.8 acres, with 146.8 acres under cultivation. A general rotation of corn two years, oats one year, wheat one year, and hay or pasture one or two years is practiced on most farms. Very little truck or fruit is grown, and wheat is the principal crop sold from the farms. Cattle and hogs are extensively raised, and practically all crops other than wheat are fed on the farm.

In preparing land for corn the pasture or hay sod is usually plowed in the fall with a 4-horse gang or a 3-horse sulky plow. In the spring this land is harrowed once each with a disk and spike-tooth harrow, and if cloddy it is often rolled (Table XXV). When corn follows corn the land is not broken until spring. It is first harrowed with a disk harrow, then plowed shallow (about 3 inches) with the 4-horse gang or 3-horse sulky plow and harrowed once or twice with the spike-tooth harrow. The corn is generally checked and planted level in rows $3\frac{1}{2}$ feet apart each way, alternating the hills with two and three grains. About three weeks after planting, the corn is harrowed with a 4-horse spike-tooth harrow. Some farmers harrow just as the corn comes up and again one week later.

Practically all the cultivating is done with 2-horse 6-shovel cultivators (3-inch shovels). Usually three or four cultivations are given in alternate directions. No cover crops are grown, but organic matter is supplied by stable manure and hay sod. No commercial fertilizer is used, but barnyard and stable manure is often applied broadcast to the corn land before planting. Both white and yellow dent varieties of corn are grown, but the white varieties predominate.

The most prevalent weeds are crab-grass, foxtail, bull nettle, cocklebur, smartweed, morning-glory, and pigweed.

TABLE XXV.—*Tillage practices with corn in Bates County, Mo., showing depth of plowing, implements used in order of use, number of times each is used, and normal yield of the crop.*

[In columns 3 to 5 and 7 to 11 the figures show the order in which the implement was used on the several farms; as, 1 = first working or cultivation, 2 = second working or cultivation, etc.]

Farm No.	Depth of plowing (inches).	Tillage after plowing and before planting.				Tillage after planting.								Normal yield per acre (bushels).
		Harrow.			All workings.	Spike-tooth harrow.	Weeder.	Roller.	2-horse cultivator.		Total cultivations.			
		Spike-tooth.	Disk.	Roller.					6-shovel.	4-shovel.	Harrow, weeder, or roller.	Other implements.	All workings.	
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1.	5	1,2			2			1	2,3,4		1	3	4	25
2.	7	1,2			2	1			2 to 5		1	4	5	35
3.	5	1,2			2				1,2,3	a 4		4	4	25
4.	6	2	1		2	1	2		3 to 6		2	4	6	25
5.	6	1			1				1 to 4			4	4	25
6.	5	2	1		2	1,2			3 to 6		2	4	6	12½
7.	6	1,2		3	3	1,2			3,4,5		2	3	5	20
8.	8	3,4	1,2		4	1			2 to 6		1	5	6	40
9.	6	1,2,3			3				1 to 4			4	4	30
10.	4	1,2			2	1,2			3,4,5		2	3	5	25
11.	4½	1,2	1	3	3	1			2,3,4		1	3	4	25
12.	6	1,2		3	3	1			2,3,4		1	3	4	25
13.	7½	2	1		2	1			2,3,4		1	3	4	40
14.	7	2	1		2	1,2			3	4,5,6	2	4	6	28
15.	6	1,2			2	1			2,3,4		1	3	4	30
16.	5	1	2		2				1 to 5			5	5	25
17.	7	1,2			2	1,2			3 to 6		2	4	6	30
18.	6	2	1		2	1			2 to 5		1	4	5	30
19.	6	3	1,2		3				3,4	1,2		4	4	40
20.	5	2	1		2	1			2 to 6		1	5	6	35
21.	6	2	1		2	1				2 to 5	1	4	5	37
22.	6	2	1		2	1			2,3,4		1	3	4	35
23.	6	3	1,2		3	1			2,3,4		1	3	4	40
24.	5	1,2			2	1			2 to 5		1	4	5	25
25.	6	2	1	3	3	1,3		2	4,5,6		3	3	6	25
Farms using..... per cent.		100	56	16		76	4	8	96	16	80			
Average.....	5.9				2.3							3.7	4.8	29.3

a Disk cultivator.

SURVEYS IN ALEXANDER COUNTY, N. C.

The soil around Taylorsville, N. C., where the tillage records (Table XXVI) for Alexander County were taken, is mostly a red sandy clay loam with a very stiff red-clay subsoil. This region is very rolling and in some places the topsoil has been washed away until only the clay is left. No tiling is necessary here, but numerous surface ditches and terraces are required to control the surface water. Few of the country roads have been macadamized, and during unfavorable weather hauling is very difficult.

Less than half of the available land is under cultivation. The cultivated fields being small and irregular in shape, 1-horse cultivators are principally used. A general type of farming is practiced on most farms. Very little labor is hired, because most of the farms are worked by the owners.

TABLE XXVI.—*Tillage practices with corn in Alexander County, N. C., showing depth of plowing, implements used in order of use, number of times each is used, and normal yield of the crop.*

[In columns 4, 5, and 7 to 11 the figures show the order in which the implement was used on the several farms; as, 1 = first working or cultivation, 2 = second working or cultivation, etc.]

Farm No.	Depth of plowing (inches).	Tillage after plowing and before planting.				Tillage after planting.								Normal yield per acre (bushels).
		Re broken with 1-horse plow.	Harrow.		All workings.	Spike-tooth harrow.	Cultivator.				Total culti- vations.			
			Disk.	Spike-tooth.			1-horse.		2-horse.		Harrow, weeder, or roller.	Other implements.	All workings.	
							4-shovel.	2-shovel.	8-shovel.	6-shovel.				
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1.	8	1		1	1	1 to 4	5 to 8				4	4	8	28
2.	8	1		1	1	1, 2, 3	4 to 7				3	4	7	15
3.	7			1, 2	2		1 to 4					4	4	25
4.	6	1		1	1	1	2 to 5				1	4	5	20
5.	5		1	2	2			1, 2, 3				3	3	25
6.	7	1			0	1	2 to 5				1	4	5	15
7.	5			1, 2	2	1, 2		3 to 8			2	6	8	50
8.	6			1, 2	2		1, 3, 4	2				4	4	20
9.	8	1			0	1, 2			3 to 6		2	4	6	55
10.	6				0		1, 2, 3					3	3	20
11.	6			1	1				1 to 4			4	4	20
12.	5½			1	1		1, 3, 4	2				4	4	15
13.	5			1	1		1, 3, 4	2				4	4	15
14.	8		1	2	2	a 1	2 to 6				1	5	6	30
Farms using, per cent.		35.7	14.3	78.6		50.0	71.4	35.7	7.1	7.1	50.0			
Average.....	6				1.1							4.1	5.1	25.2

a Weeder.

This land when properly treated is very productive, but when organic matter is not supplied the crop yields are low. No set rotations are followed, but an intertilled crop is usually followed by small grain, and the small-grain crops are followed by corn or cotton. Tobacco is grown on a few farms, but not so extensively as it was a few years ago. The leading money crop is cotton. Enough corn, wheat, and oats are grown for home use, and some wheat is sold. Considerable rye is grown for grain and also for green feed in the early spring. Very little fruit or truck is grown except for local demands, and few cattle or hogs are kept.

In preparing land for corn, about half the plowing is done in the fall with a 2-horse plow. In the spring, before planting, this fall-plowed land is rebroken with a 1-horse plow and the rest is broken with the 2-horse plow. After plowing, very little preparation is given before planting. Usually the land is harrowed once or twice with a spike-tooth harrow. A few farmers use a disk harrow. The corn is planted level and in drills 4 feet apart, with one stalk every 2 feet in the drill. Most of the planting is done by hand. A few farmers use a 1-horse planter.

When the corn is up the field is usually harrowed once or twice with a spike-tooth harrow. After this most of the cultivating is done with a 1-horse 4-shovel cultivator. The 1-horse 2-shovel cultivators are frequently used and occasionally 2-horse 6 and 8 shovel cultivators are found. Four or five workings are usually given.

Considerable hand labor is used in chopping out weeds and replanting. Practically all the corn grown is of the white dent varieties. A few farmers grow crimson clover as a winter cover crop with good results.

Commercial fertilizer is used only in small quantities and comparatively little stable manure is produced. The most prevalent weeds are crab-grass, sheep sorrel, Spanish needle, cocklebur, and ragweed.

SURVEYS IN OKLAHOMA COUNTY, OKLA.

The tillage records for Oklahoma (Table XXVII) were taken in the prairie section of northwestern Oklahoma County, just west of Edmond.

The county is divided into sections, and practically every section line is a public road. Through the prairie section these roads are in fair condition all the year except during very wet weather.

Most of the farms are worked by the owners. As a rule the farmers have exceptionally good houses and outbuildings.

The soil consists of a dark silt loam 10 to 20 inches deep, which grades into a heavier silty clay subsoil. The subsoil is almost impervious and affords poor drainage conditions. It is hard for the crop roots to penetrate this subsoil, and the crops suffer badly during either wet or dry weather. The country is rolling enough to afford good natural drainage, but not steep enough to interfere with the use of improved machinery. There is very little timber in this section, and practically all the land is in cultivation or grass. The farms are divided into large uniform fields of convenient shape.

This is a comparatively new section, and the settlers came from all parts of the country and brought with them the methods which were employed in the locality from which they came, so the systems followed are not uniform.

Very little fruit or truck is grown. A large part of the land is in pasture, and cattle and hogs are extensively raised. No set rotations are practiced. The principal crops grown are corn, wheat, oats, cotton, alfalfa, kafir, and milo. Unless seasons are very favorable cotton does not yield well, but it is one of the principal money crops. Alfalfa is grown mostly on the bottom lands near streams. A few farmers are growing it with success by irrigation. This crop is often utilized in hog pastures.

TABLE XXVII.—*Tillage practices with corn in Oklahoma County, Okla., showing depth of plowing, implements used in order of use, number of times each is used, and normal yield of the crop.*

[In columns 4 to 7 and 9 to 15 the figures show the order in which the implement was used on the several farms; as, 1 = first working or cultivation, 2 = second working or cultivation, etc.]

Farm No.	Depth of plowing (inches).	Tillage after plowing and before planting.							Tillage after planting.										Normal yield per acre (bushels).
		Bedded as broken.	Harrow.		Rows run with lister.	Lister and planter combined.	All workings.	Spike-tooth harrow.	Cultivator.					Mowing-machine wheel.	Total cultivations.				
			Spike-tooth.	Disk.					2-horse.				1-horse 5-shovel.		Harrow, weeder, or roller.	Other implements.	All workings.		
									Lister.	4-shovel.	6-shovel.	Disk.							
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	
1.			1			1		1		1, 2		3, 4					4	4	20
2.	4			1			2	2	1		2, 3, 4					1	3	4	10
3.	5			1			2	2			2, 3			1, 2			3	3	10
4.	5			1			2	2	1			4				1	3	4	12
5.	6			1, 2			3	3	1		2, 3, 4					1	3	4	20
6.	6			1			2	2		1, 2	3						3	3	15
7.	4			1			2	2		1, 2, 3		4					4	4	30
8.	5			1			2	2	1		2, 3					1	2	3	30
9.						1	1	1		1, 2, 3		4					4	4	35
10.						1	1	1		1, 2, 3		4					4	4	20
11.	5			1			2	2	1				2, 3, 4			1	3	4	16
12.					1	2		2				1, 2, 3		4			4	4	10
13.	6						1	1		1, 2	3						3	3	25
14.	7			1			2	2	3	1, 2	4, 5					1	4	5	30
15.	6							0			1, 2, 3						3	3	25
16.							1	1		1	2, 3, 4						4	4	4
17.								0			1, 2, 3						3	3	20
18.	3	1	1			2	2			1, 2	3		4				4	4	40
19.	4				1		1	1			2, 3					1	2	3	25
20.							0	1, 2			3, 4					2	2	4	40
21.	6			1	2			2	1			2, 3, 4		5	6, 7	1	6	7	45
Farms using... per cent.		9.5	52.4	9.5	14.3	66.7		42.8	42.8	66.7	33.3	14.3	9.5	4.8	42.9		3.4	3.9	
Average.	5.6						1.5												23.9

The methods of cultivating corn are quite variable, but in regard to crop yields, soil fertility and tillage methods are minor factors as compared to the amount of rainfall during the growing season. A few farmers plow the corn land in the fall and then rebreak in the spring just before planting. The common practice is to break the land level, harrow with a spike-tooth harrow, and lay off the rows with a double moldboard plow commonly known as a lister or middle buster, which plows out a broad, deep furrow, throwing the dirt to either side. The corn is planted in the bottom of this furrow.

Most farmers use the combination planter and lister, which is the shovel plow and planter combined. This implement plows out the furrow and plants the corn at one operation. Frequently corn is planted with this implement without any previous preparation of

the land. Especially is this true when corn follows corn or cotton. For such work a 3-horse or 4-horse team is used and the plow employed has a broad shovel which breaks practically all the row. No difference in the yield is noted from the different methods of preparing the land. About 90 per cent of the corn is listed and planted in drills 3 to 3½ feet apart with one stalk every 18 inches in the drill.

After planting, a spike-tooth harrow is frequently used just as the corn comes up. A disk cultivator especially designed for cultivating listed corn is extensively used for the first cultivation. The 1-row cultivator of this type (fig. 36) is constructed on a sled which

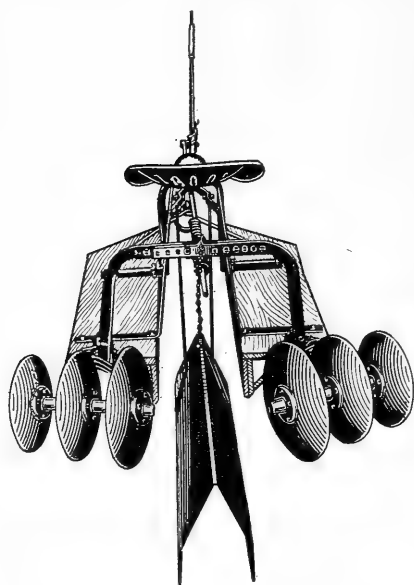


FIG. 36.—A type of 2-horse disk cultivator used in Oklahoma and western Kansas for cultivating listed corn.

straddles the corn row and protects the corn plants from being covered with dirt from the disk cultivators which run on either side of the row. The 2-horse 4 and 6 shovel cultivators and disk cultivators are used for the later cultivations. A few farms use a 1-horse 5-shovel cultivator. Usually three or four cultivations are given. After the corn gets too high to cultivate, some farmers will, with one horse, drag a mowing-machine wheel between the rows, which destroys nearly all the small weeds and forms a shallow dust mulch.

Practically no cover crops are grown and no commercial fertilizer is used.

The yellow dent varieties of corn are principally grown.

The most prevalent weeds are smartweed, crab-grass, ragweed, bull nettle, artichoke, and Johnson grass.

SURVEYS IN PIKE COUNTY, ALA.

The tillage records for Alabama (Table XXVIII) were taken in Pike County near Troy. The soil in this region is of a sandy or sandy-loam type, usually dark red in color, and underlain with a reddish sand-clay subsoil. The land is very irregular and in some places extremely rolling. Drainage is principally obtained by means of numerous terraces, which divide the fields into small, irregular-shaped areas. These terraces are usually about 25 yards apart and are so constructed that they can not be worked over. On most of them Bermuda grass is grown to prevent erosion.

TABLE XXVIII.—*Tillage practices with corn in Pike County, Ala., showing depth of plowing, implements used in order of use, number of times each is used, and normal yield of the crop.*

[In columns 4, 5, and 7 to 11 the figures show the order in which the implement was used on the several farms; as, 1 = first working or cultivation, 2 = second working or cultivation, etc.]

Farm No.	Depth of plowing (inches).	Tillage after plowing and before planting.				Tillage after planting.								Normal yield per acre (bushels).
		Bedded as broken.	Rows run with—		All workings.	1-horse plow.		Cultivator.		1-horse sweep.	Total cultivations.			
			Lister.	Bull-tongue plow.		Turning.	1-shovel.	1-horse spike-tooth.	2-horse 1-row disk.		Harrow, weeder, or roller.	Other implements.	All workings.	
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1.....	10	1	1		1	2	1			3		3	3	30
2.....	7	1		1	1		2	1		3, 4, 5		5	5	25
3.....	6		1	2	2			1, 4, 6		2, 3, 5		6	6	25
4.....	10	1				1, 4	2, 3			3, 5		5	5	18
5.....	10	1				3	2	1		4		4	4	33
6.....	10		1		1	1, 4	2			3, 5		5	5	40
7.....	6	1				2, 4	1			3, 5		5	5	20
8.....	9	1	1		1	1, 2, 3, 5				4, 6, 7		7	7	20
9.....	6	1				2, 4	1			3, 5		5	5	20
10.....	10	1				1				2, 3, 4		4	4	12
11.....	5	1						1, 2, 3		4		4	4	20
12.....	4	1			1	1	2			3, 4		4	4	15
13.....	5	1				1, 3				2		3	3	20
14.....	8		1		1	1, 3				2, 4		4	4	
15.....	6		1		1	4		1	2	3, 5		5	5	18
16.....	7	1	1		1	2, 4		1		3, 5, 6		6	6	
17.....	4½	1				1, 3		4		2		4	4	
18.....	3	1				1, 3				2, 4		4	4	
19.....	5	1			1	2, 4	1			3, 5, 6		6	6	
20.....	5			1		2, 3	4	1		5		5	5	31
21.....	4	1		1	1	1, 3				2, 4		4	4	
Farms using..... per cent.	80.9	33.3	23.8			85.7	47.6	38.1	4.8	100	0			
Average.....	6.7				0.6						4.7	4.7	23.1	

Only a few of the leading roads have been macadamized, and during wet weather hauling is difficult. Owing to the mild winters and the scarcity of cattle, very cheap barns and outbuildings are found on most farms. Because of so many cheap tenant houses and the lack of good outbuildings, the country does not look prosperous, but the landowners have good dwelling houses and appear well to do.

Some of the farms are operated by the owners with hired labor, but most of the farming is by the tenant system, in which the landlord furnishes all supplies and supervises the work. The land is often owned in large tracts and operated by a number of tenants, each tenant cultivating about 25 acres.

No general rotation is practiced. The principal crops are corn and cotton, with about two-thirds of the land in cotton. Some oats are grown on most farms. In the southwestern part of the county, considerable sugar cane is grown. Peanuts and velvet beans are

planted between the corn rows at the last cultivation. These are either harvested or pastured by cattle and hogs after the corn is gathered. By this means a few cattle and hogs are grown. A good part of the land is pasture, but the native grasses afford poor grazing. Little fruit or truck is grown, and the farm income is principally from cotton.

Under the tenant system here each tenant is usually given one mule and as much land as this mule can cultivate, so that practically all the cultivation is with 1-horse implements. In breaking the land for corn, sometimes an extra mule is furnished and the land is broken with a 2-horse plow, but the general practice is to break the land with a 1-horse plow, and instead of flat breaking it is thrown into ridges or beds the width apart the corn

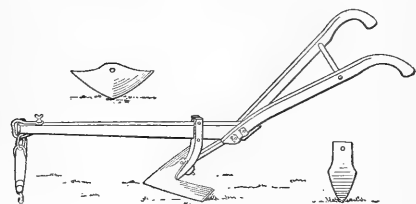


FIG. 37.—A 1-horse 1-shovel plow with cotton sweep attached, used to cultivate corn in the Southern States. At the top is a broad shovel or solid sweep; below, a narrow shovel, used in making furrows for planting.

rows are to be. Sometimes a narrow strip of land is left between these ridges. This strip is plowed out with a 1-shovel plow (fig. 37) running very deep, and the corn is then planted in the furrow.

A few farmers break the land level and then lay off the rows with a double moldboard plow known as a lister, or middle buster, which throws the dirt to each side and leaves a broad, deep furrow. The corn is planted in the bottom of this furrow. After plowing, the land is usually given no further preparation before planting.

The corn is planted in drills from 5 to 6 feet apart, with one or two stalks every 2 feet in the drill, and either between beds or in the bottom of a furrow. After the corn is up, a 1-horse spike-tooth cultivator (fig. 38) is often used for the first cultivation, but more often a 1-horse turning plow or a 1-horse 1-shovel plow, known as a bull tongue, is used. One furrow is run on either side of the row, throwing the dirt toward the middle of the row and away from the corn, leaving the corn on a narrow ridge. Later, the middle is plowed out with the turning plow, throwing the dirt toward the corn. This cultivation tears down the ridge and leaves the land almost level. After this, the cultivating is done with broad sweeps covering all the middle with three or four

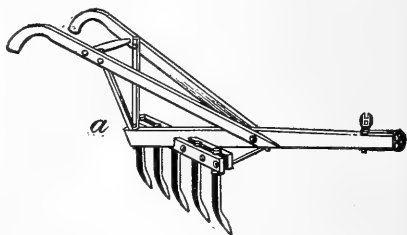


FIG. 38.—A 1-horse spike-tooth cultivator, or side harrow, used in the rolling areas of Alabama and Mississippi.

furrows. Three to six cultivations are usually given, depending on the amount of rainfall and the weed growth. The white dent varieties of corn are almost exclusively grown.

Commercial fertilizer is extensively used for all crops, but little stable manure is produced. Practically no cover crops are grown, but winter weeds, principally life everlasting (cudweed), often make considerable growth during the fall and winter months, which make winter cover crops not so necessary.

The most prevalent weeds are life everlasting, Johnson grass, purslane, cocklebur, and crab-grass.

SURVEYS IN HOLMES COUNTY, MISS.

The tillage records for Mississippi (Table XXIX) were taken in Holmes County, mostly around Lexington. The upland soils are of a silt-loam type, dark yellow in color, and from 6 to 10 inches deep. The subsoil is of a heavier silt loam, containing more clay and darker in color. Along the streams the bottom lands are much heavier and more level land is found, but the uplands are very rolling and erode easily. Practically none of the land is tile drained and very few surface ditches are found. Only about one-half the land is cultivated, and after a field has been depleted of its fertility by continuous cropping and erosion it is abandoned and other land cleared.

Only a few of the roads have been macadamized, and hauling is very difficult during bad weather. The land is mostly owned in large tracts or plantations and is worked by negro tenants under the supervision of the owner. The landowners have good houses and appear prosperous, but the tenant houses and the lack of good out-buildings detract from the prosperous appearance of the country.

The principal crops grown are corn and cotton, with some oats for hay. In the southwestern part of the county sugar cane is extensively grown. Truck crops, especially strawberries and cabbage, are much grown in the eastern part of the county and shipped to the Chicago market. Near Lexington very little truck or fruit is grown. Considerable land is in native grass, which furnishes pasture for a good part of the year, and a few cattle and hogs are kept. It is a common practice to sow cowpeas broadcast between the corn rows at the last cultivation and after the corn is gathered pasture them off with cattle and hogs. The principal money crop is cotton, but since the boll weevil has reached this section more corn and less cotton are grown. No rotations are practiced, and the land is usually kept in corn or cotton until the crop yields become so low that its cultivation is not profitable.

TABLE XXIX.—*Tillage practice with corn in Holmes County, Miss., showing depth of plowing, implements used in order of use, number of times each is used, and normal yield of the crop.*

[In columns 4 to 10 and 12 to 20 the figures show the order in which the implement was used on the several farms; as, 1 = first working or cultivation, 2 = second working or cultivation, etc.]

Farm No.	Tillage after plowing and before planting.										Tillage after planting.										Normal yield per acre (bushels).					
	Depth of plowing (inches).	Bedded as broken.	Harrow.			Bedded with 1-horse turning plow.	Rows run with—		All workings.	Harrow.	1-horse plow.				Cultivator.		Total cultivations.									
			Spike-tooth.	Disk.	Acme.		Plank drag.	8			9	10	11	Spike-tooth.	Disk.	Narrow.	Broad.	2-shovel.	Turning.	1-horse sweep.		1-horse spike-tooth.	2-horse 8-shovel.	Harrow, weeder, or roller.	Other implements.	All workings.
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24			
1	5	1	1	1	1	1	2	1	2	1	1	1,2	2	2	2	2	3	3	4	2	2	3	4	45		
2	4	1	1	1	1	1	3	1	2	3	3	1	2	2	2	3	2,3	4	1	1	3	4	36			
3	4	1	1	1	1	1	3	1	2	3	3	1	2	2	2	3	1,4	4	2	2	3	4	40			
4	6	1	1	1	1	1	4	1	2	0	4	2	2	2	1	1,4	3	4	2	2	4	4	25			
5	5	1	1	1	1	1	5	1	2	0	5	2	2	2	1	1,4	3,5	4	4	2	4	4	20			
6	4	1	1	1	1	1	6	1	2	1	6	2	2	2	1	1,4	1,2	6	4	2	6	4	25			
7	4	1	1	1	1	1	7	1	2	2	7	2	2	3	1	1,4	4 to 7	3	4	2	7	4	10			
8	6	1	1	1	1	1	8	1	2	2	8	2	2	3	1	1	4 to 7	3	4	2	7	4	20			
9	5	1	1	1	1	1	9	1	2	1	9	2	2	2	2	3	1,4,5	3	3	2	7	3	20			
10	4	1	1	1	1	1	10	2	1	2	1,2	2	2	2	2	2	3,4,5	3	2	2	3	3	30			
11	8	1	1	1	1	1	11	2	2	2	2	2	1	1	3	3	1,2	2	2	2	3	3	15			
12	8	1	1	1	1	1	12	3	2	2	3	3	1	2	3	3	1,2	4	4	1	3	3	18			
13	8	1	1	1	1	1	13	3	3	2	3	3	2	2	3	3	1,2	4	4	1	3	3	15			
14	8	1	1	1	1	1	14	3	3	3	3	3	2	2	3	3	1,2	4	4	1	3	3	15			
15	4	1	1	1	1	1	15	3	3	0	3	3	2	2	3	4	1,2,3	3,4,5	5	1	5	5	20			
16	8	1	1	1	1	1	16	3	3	0	3	3	2	2	3	4	1,2,3	3,4,5	5	1	5	5	10			
17	4	1	1	1	1	1	17	3	3	0	3	3	2	2	3	4	1,2,3	3,4,5	5	1	5	5	20			
18	6	1	1	1	1	1	18	3	3	0	3	3	2	2	3	4	1,2,3	3,4,5	5	1	5	5	20			
19	6	1	1	1	1	1	19	3	3	0	3	3	2	2	3	4	1,2,3	3,4,5	5	1	5	5	20			
20	4	1	1	1	1	1	20	3	3	0	3	3	2	2	3	4	1,2,3	3,4,5	5	1	5	5	20			
21	4	1	1	1	1	1	21	3	3	0	3	3	2	2	3	4	1,2,3	3,4,5	5	1	5	5	20			
22	4	1	1	1	1	1	22	3	3	0	3	3	2	2	3	4	1,2,3	3,4,5	5	1	5	5	20			
23	4	1	1	1	1	1	23	3	3	0	3	3	2	2	3	4	1,2,3	3,4,5	5	1	5	5	20			
24	4	1	1	1	1	1	24	3	3	0	3	3	2	2	3	4	1,2,3	3,4,5	5	1	5	5	20			
25	4	1	1	1	1	1	25	3	3	0	3	3	2	2	3	4	1,2,3	3,4,5	5	1	5	5	20			
Farms using... per cent.	5.1	72	52	20	4	4	28	8	20	1.4	20	8	36	12	4	72	96	64	4	28	4.3	4.7	22			
Average																										

a Weeder.

On account of the tenant system employed and the rolling condition of the land, most of the cultivating is done with 1-horse implements. In preparing the land for corn, a disk harrow is often run over the field some time during the winter to chop up the old cotton or corn stalks. Most of the breaking is done in the spring, but a few farmers break the land in the fall and then rebreak in the spring. Instead of "flat breaking," practically all the land as broken is made into beds or ridges the width apart the corn rows are to be. A good part of this breaking is done with 1-horse plows, but during the last few years 2-horse plows have come into more general use and the land is broken deeper than formerly. After breaking, these ridges are usually harrowed down almost level with a spike-tooth or disk harrow before planting. Often a bull tongue or subsoil plow is used to run off the rows and a very deep furrow plowed out, in which the corn is planted. On the bottom lands the corn is planted on the beds, but on the uplands it is planted between the beds. Practically all the planting is in drills $3\frac{1}{2}$ to 4 feet apart, with one stalk every 2 feet in the drill.

After planting, the methods of cultivating corn are not very uniform. Until recent years, the 1-horse turning plows and the cotton sweeps were practically the only cultivators used, but during the past few years more surface cultivation has been practiced.

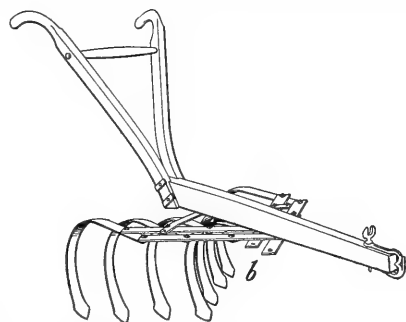


FIG. 39.—A spring-tooth 1-horse or "gée whiz" cultivator, used in parts of Alabama and Mississippi.

After the corn is up, a few farmers use a 2-horse harrow for the first cultivation, but more often 1-horse spring-tooth cultivators (fig. 39) are used, giving one or two furrows to the middle. The spike-tooth cultivator is used more generally than any other implement in this section. The 1-horse turning plows and the 1-horse 1-shovel plows are often used to plow down the middles and level up the rows. For the last cultivation a cotton sweep is often used. Very few 2-horse cultivators are found.

Practically no cover crops are grown, and very little commercial fertilizer is used. Very little stable manure is produced because the cattle stay in the field during most of the year.

The white dent varieties of corn are principally grown.

The most prevalent weeds are crab-grass, bindweed, Bermuda grass, Johnson grass, and cocklebur.

SURVEYS IN RUSSELL COUNTY, KANS.

Russell County is located in the central-western part of Kansas and is primarily a wheat-producing section. This is a typical prairie

region, of broad, gently sloping ridges and level valleys. No drainage is required. Some parts of this area are extremely rolling and rugged. These lands are used for grazing purposes.

The country has not yet been fully developed. Only a few of the principal roads have been improved. On account of the extra large size of the farms the country is thinly populated, which makes it impracticable to have schools and churches conveniently near. Practically no timber is grown and the farmhouses and barns are built of a convenient soft native stone, which hardens when exposed to the air. The absence of trees around the farm homes gives to the country a rather desolate appearance. All the farm lands are fenced, the fence posts being of stone.

TABLE XXX.—*Tillage practices with corn in Russell County, Kans., showing depth of plowing, implements used in order of use, number of times each is used, and normal yield of the crop.*

[In columns 3 to 8 the figures show the order in which the implement was used on the several farms; as, 1 = first working or cultivation, 2 = second working or cultivation, etc.]

Farm No.	Depth of plowing (inches).	Tillage after planting. ^a									Normal yield per acre (bushels).
		Spike-tooth harrow.	Plank drag.	Cultivator.				Total cultivations.			
				Lister.		2-horse.		Harrow, weeder, or roller.	Other implements.	All workings.	
				2-horse.	4-horse 2-row.	4-shovel.	6-shovel.				
1	2	3	4	5	6	7	8	9	10	11	12
1	3			1, 2			3	0	3	3	10
2	6				1, 2	3		0	3	3	31
3	5	2, 4			1, 3	5		2	3	5	20
4	8		2		1, 3			1	2	3	10
5	6	1			2, 3	4, 5		1	4	5	20
6	6				1, 2	3		0	3	3	10
7	6	1				2, 3, 4		1	3	4	25
8	6	2			1, 3			1	2	3	15
9	6				1, 2	3		0	3	3	25
10	6				1, 2		3, 4	0	4	4	25
11	5	2			1, 3		4, 5	1	4	5	20
12	3				1, 2		3	0	3	3	20
13	5	1			2, 3		4, 5	1	4	5	20
14	7	1			2, 3		4	1	3	4	20
15	5				1		2, 3, 4	0	4	4	20
16	5	2		1	3, 4		5	1	4	5	25
17	6	2			1, 3	4		1	3	4	25
18	4		2		1, 3			1	2	3	18
19	4	1			2, 3		4	1	3	4	30
20	5				1, 2		3	0	3	3	20
21	5	1			2	3, 4		1	3	4	20
22	6				1, 2		3	0	3	3	20
23	6				1, 2, 3		4, 5	0	5	5	20
24	7				1, 2		3	0	3	3	20
25	7				1, 2		3	0	3	3	20
Farms using per cent		44	8	8	92	32	56	52			
Average	5½								3.2	3.8	20.4

^a No tillage was given after plowing and before planting.

No general rotations are practiced. Wheat is the principal money crop, and on many farms it is the only crop grown. Corn, kafir, and

cane are grown only on the bottom lands. In collecting the data shown in Table XXX only those farms which grow corn were visited. Some alfalfa is grown on the bottom lands and in favorable seasons does well.

Most of the land is farmed by the owners, or the farmer may own a farm and rent other land in addition. The average size of the farms visited in this county is 655 acres, with 331 acres under cultivation. These farms are somewhat larger than the average for this region. The land in this section is very fertile and productive, and the limiting factor in crop yields is the amount of rainfall.

The bottom-land farmers, because they can grow forage crops, keep more cattle and swine than the upland farmers, and their sources of farm income are cattle, hogs, and wheat. For the upland farms the income is principally from wheat. Not enough fruit or truck is grown to supply home demands.

The tillage methods with corn here are exceptionally uniform and represent the methods employed throughout the semiarid region of western Kansas and western Nebraska. Corn usually follows corn or kafir. The land is generally harrowed in the spring with a disk harrow, and without plowing or further preparation corn is planted with a 4-horse combination lister and planter. This planter has a double mold-board and usually runs about 5 inches deep, throwing the dirt in both directions, and the corn is planted in the bottom of this furrow. The rows are usually $3\frac{1}{2}$ feet apart, with one stalk every 18 or 20 inches in the drill. In opening up this furrow most of the land is broken, but there is a strip directly between the rows which is not plowed. This strip is broken up during the cultivation.

After the corn is up, the first cultivation is most often given with a 4-horse 2-row disk cultivator designed for cultivating listed corn. At this cultivation the dirt is thrown away from the corn and the ridges made higher. These ridges are next harrowed with a spike-tooth harrow or plank drag and partly torn down. The next cultivation is given with the same 4-horse 2-row cultivator, with the disks adjusted so as to throw dirt to the corn, tearing down the ridges between the rows. The next and last cultivation is usually given

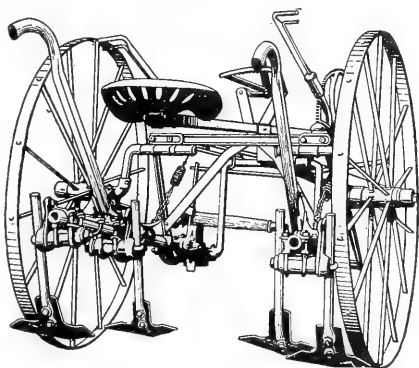


FIG. 40.—A 2-horse 4-shovel cultivator with sweeps attached instead of shovels. This implement is extensively used in cultivating corn in Texas and Oklahoma.

with a 2-horse 4-shovel or 6-shovel cultivator (fig. 40), and this leaves the land about level.

No cover crops are grown and no commercial fertilizers used. Cattle spend most of their time in the pastures, so little manure is saved.

The yellow, white, and red varieties of dent corn are grown.

The principal weeds of this section are cocklebur, Russian thistle, pigweed, bindweed, sand bur, and sunflower.

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BULLETIN No. 321



OFFICE OF THE SECRETARY
Contribution from the Office of Farm Management
W. J. Spillman, Chief

Washington, D. C.



January 12, 1916

COST OF FENCING FARMS IN THE NORTH CENTRAL STATES.

By H. N. HUMPHREY, *Scientific Assistant.*

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The question of fencing was not considered a problem by the pioneer farmer. Timber was abundant and cheap, as was also the necessary labor required to work it up in the form of fences. Land was relatively plentiful and cheap, and it did not matter so much if rail fences and hedgerows did occupy considerable of it. Since pioneer days, however, farming conditions have undergone a radical change. At the same time the mode of fencing farms has undergone an evolution, this evolution at all times keeping pace with the changing farming conditions and adapting itself to them as best it could. Thus has come the transition from early agricultural conditions, with its cheap land, plentiful timber supply, and rail fences, to the farming of the present day, with high land values and a scarce and ever-decreasing supply of timber. The present-day farmer does not have at his disposal an almost unlimited supply of high-grade timber and labor with which to build fences, and he must incur a big outlay of money in securing the necessary materials and labor. To him the matter of fencing his farm suitably and economically has become a problem.

The enormous proportions which the farm-fence problem has assumed to the farmers of the United States can best be shown by the

NOTE.—This bulletin will be of interest to farmers and students of agricultural conditions in the North Central States.

use of figures given in the reports of the last census, combined with data obtained in the studies of this office. In 1909 there were 6,361,502 farms in the United States, averaging 138.1 acres each. It has been found that the average 140-acre farm requires 6 rods of fence to the acre, or a total of 828.6 rods to the farm. This would mean that there were in round numbers 5,271,000,000 rods or 16,472,000 miles of fence in use in the United States in 1910. This amount of fence would encircle the earth about 659 times. To replace this with only a medium grade of woven-wire fence, a type which has been very commonly used by American farmers in the past, would cost, at the rate of 65 cents per rod for wire, posts, miscellaneous materials, and labor, \$3,426,241,362, which is 8.3 per cent of the total value of all farm property, 12 per cent of the value of all farm land, 54.1 per cent of the value of farm buildings, 69.5 per cent of the value of domestic animals, poultry, and bees on farms, and more than double the value of all implements and machinery on farms, according to the values estimated for these items by the last census. It must be borne in mind, however, that the figures represent the first cost of fences, while the census figures represent the present value of buildings and machinery. Therefore the ratio will not be quite as great.

It may be fairly assumed that the average woven-wire fence, constructed of materials which will permit its erection at a cost not to exceed 65 cents per rod, will not give satisfactory service for more than 15 years. Assuming this to be the case, the renewal cost of farm fences in the United States would amount to \$228,416,090 annually. Data obtained by this office show that there is an annual repair charge of 0.024 cent per rod on woven-wire fence. At this rate the repair charges on all fences in the United States will total \$126,507,373. The interest on investment at 5 per cent is \$171,312,068. Totaling these three items gives an annual upkeep charge of \$526,235,531, or a cost of \$82.72 per farm, or 59 cents per acre, or 15.37 per cent of the value of the fence as above estimated. There is, of course, a great deal of fencing that is not made of woven wire, but the depreciation, repair, and investment charges on it would be even greater than in the case of woven wire.

The relation of farm fences to the economics of farming has received very little attention in this country—far less than its importance would seem to justify. It was thought, therefore, that a study of farm fences conducted in an area where they were most indispensable might develop some facts that would be of value in establishing economic standards for fencing. It is the purpose of this bulletin to present the essential features of farm-fence practice as found in the North Central States, and to make suggestions to those interested in fence management.

AREAS COVERED BY THE INQUIRY AND FARMING TYPES.

Data were obtained from the 12 North Central States as shown in figure 1.

In Areas 1, 2, and 3 the type of farming followed is the growing of corn, small grain, and forage crops, and the marketing of the greater part of these crops by feeding to live stock on the farm. The stock kept is maintained principally on pastures during the pasture season. Sometimes the pasture field has a regular place in the crop rotation and is changed about from season to season. Another practice is to allow the land to remain in pasture for a long term of years, in some cases indefinitely; the term "permanent pasture" is applied to lands handled in this manner. More fences are required on farms

where the pasture forms a part of the rotation than on farms where permanent pastures are used; however, on most farms much of the land is pastured after the crops have been removed, and in some instances the live stock are turned into the field to harvest the crop. It is in these areas where much stock is kept that considerable fence is required to utilize the land to the best advantage.

Area 4 typifies a country where extensive farming is followed. There are two distinctive types of farming in this area; one is grain growing and the other live-stock farming. The grain farms carry little stock other than the horses required to do the farm work, while on the live-stock farms a relatively small area is in field crops and the stock is carried during the growing season on permanent pastures. Both of these systems require very little farm fence as compared to the fence required on farms in areas where an intensive system of mixed farming is followed.

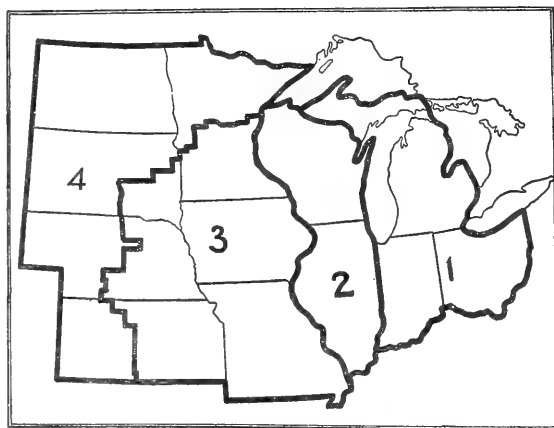


FIG. 1.—The territory covered by the investigation was divided into four areas, as shown here. These areas are referred to by their respective numbers.

METHOD OF INVESTIGATION.

The data here presented were obtained by circular letter from farmers in the area designated. The data in the tables were compiled from the reports of 5,837 farmers. Great care was taken not

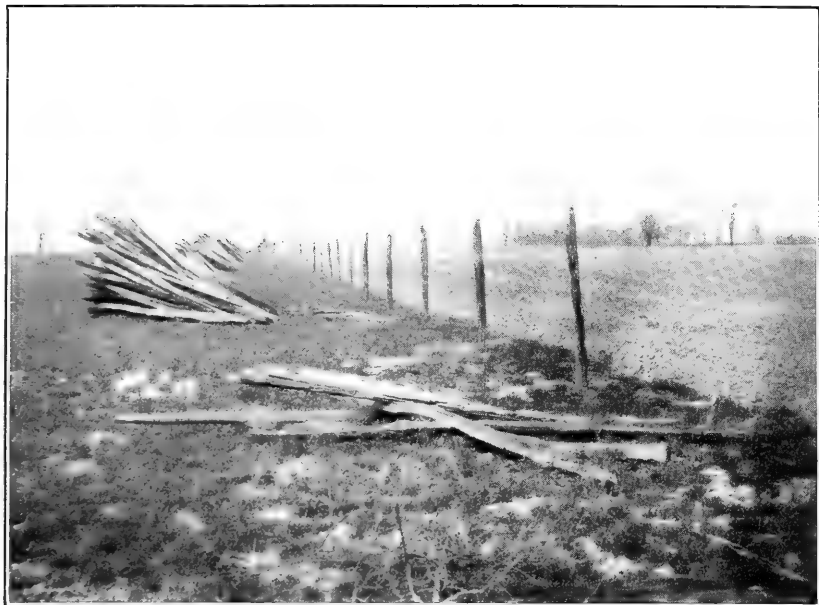
to include reports which were incomplete, and many such were discarded. It is believed a sufficient number of reports were secured from all parts of the area studied to furnish data which would be representative of the entire area.

LOCAL REQUIREMENTS AND ADAPTATION.

There are four main types of fence in use in this country—wire, wooden, hedge, and stone—but there are almost numberless modifications of these types. Present-day conditions, with high-priced land, scarcity of timber, and the consequent high cost of materials for wooden fences, as well as the higher wages paid to farm labor, have made it impracticable in most localities for the farmer to construct any but wire fence. Any data or discussion in this manuscript in regard to the construction of the most economical kinds of fence will therefore refer to the use of different types of wire fencing.

Wooden, stone, and hedge fences, at the time they were built, were well suited to the conditions, and in most instances they were the logical fences to construct. For example, the New England farmer cleared most of his land in 6 or 10 acre lots. He could burn the wood and get it out of the way, but the easiest way to remove stones which would interfere with the cultivation of the fields was to pile them up in walls around the fields. This served the double purpose of removing the stone from the land and making a fence. The settlers of Ohio and Indiana had different conditions to meet. They also had to remove the timber from their lands, but they did not have to contend with stone to any appreciable extent; so instead of burning all the timber they split some of it up into rails and constructed their fences of them. The farmers who settled in the prairie regions of Illinois, Iowa, Kansas, Nebraska, and other Western States had neither timber nor stone to remove from their farms or to use in the construction of fences. Wire fences at that time were unknown; they naturally planted hedges, which answered both as a fence and as a windbreak.

Stone walls have in many instances become racked, and are hence no longer serviceable. Material for reconstructing rail fences is usually lacking. Hedgerows make very poor fence; they are also expensive. All of these types occupy excessive ground space, form breeding places for weeds and insects, and require much labor to keep them in order. For these reasons the above-mentioned types of fence are gradually disappearing. There are still many stone, wooden, and hedge fences in use, but as fast as they become unserviceable they are being removed and replaced with wire. (Plate I.)



F 117023

FIG. 1.—WORM RAIL FENCES ARE RAPIDLY BEING REPLACED BY WOVEN-WIRE FENCES.



F 117021

FIG. 2.—STONE WALLS FORM A HARBOR FOR ANIMALS AND INSECTS AS WELL AS FOR BRUSH AND WEEDS. ON ACCOUNT OF THE LARGE AMOUNT OF LABOR REQUIRED IN THEIR CONSTRUCTION THEY ARE VERY COSTLY.

DISTRIBUTION OF THE VARIOUS TYPES OF FENCE.

The percentage of the different kinds of fence used in the area studied is shown in Table 1.

TABLE 1.—*Percentage of different types of fence used in the various localities studied.*

Area.	Wide woven wire.	Narrow woven wire with barbed wires.	Barbed and smooth wire.	Hedge.	Types of wooden fencing.	Stone fence.
	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>
Western Dakota, Nebraska, Kansas, and northern Minnesota.....	5.5	10.2	84.0	0.03	0.3	0.0
Eastern Dakota, Nebraska, Kansas, and southern Minnesota.....	8.8	20.0	63.0	6.4	.6	.6
Iowa.....	8.0	45.5	43.5	2.1	.9	.0
Missouri.....	13.8	49.4	27.2	5.6	3.8	.04
Wisconsin.....	13.5	33.4	49.8	.04	2.3	.8
Illinois.....	11.4	41.7	29.0	12.4	5.5	.0
Michigan.....	55.9	11.8	11.9	.6	19.7	.0
Indiana.....	53.3	18.0	12.9	1.6	14.1	.05
Ohio.....	59.8	3.8	7.0	1.2	27.9	.05

WIRE FENCES.

From Table 1 it may be observed that the greater part of the fencing now in use is constructed of some form of wire. In the western portion of the area studied 84 per cent of the fencing used is made from barbed and smooth wire and 15.7 per cent from the different types of woven wire. In Ohio the opposite is the case, as shown by the fact that only 7 per cent of the farm fences is made from barbed and smooth wire, while 63.6 per cent is constructed from woven wire. It will be noticed that from these two extremes there is a gradual gradation, the amount of woven wire increasing from west to east and the amount of barbed wire decreasing. In this study the woven wire used on farms has been divided into two general classes. Narrow woven wire does not exceed 42 inches in height, with which two or more barbed wires are used to make the fence the desired height. A woven-wire fence over 42 inches high, and which may or may not be supplemented by the use of barbed wire, has been classed as high woven wire. Table 1 shows that the use of the high and the low types is confined to a marked degree to certain well-defined areas. In Ohio, Michigan, and Indiana the greater part of the woven-wire fence used is "wide" (fig. 2), while in the remainder of the area studied most of the woven-wire fence in use is "narrow" (fig. 3). The distribution of barbed and woven wire fencing in the various areas may be explained in part by the requirements of the different kinds of farming followed in the areas.

It is not so easy to account for the use of high woven wire in one area and of low woven wire in another when both follow a very similar

farming system and have the same fencing needs. This may be explained by the fact that Area No. 1 is an older established community than either Areas 3 or 4. Most of Area No. 1 was well fenced with the different types of wooden fence before the days of wire fencing. Farmers here did not, therefore, use much barbed wire, which was the first to be placed on the market. The farms in Areas No. 2 and No. 3 were not as completely fenced at this time, and considerable barbed wire was used in fencing them (fig. 4). Woven-wire fence was developed later, but was placed on the market while the wooden fences in Area No. 1 were yet in use. On account of the high price of the first woven wire, it was made narrow and of

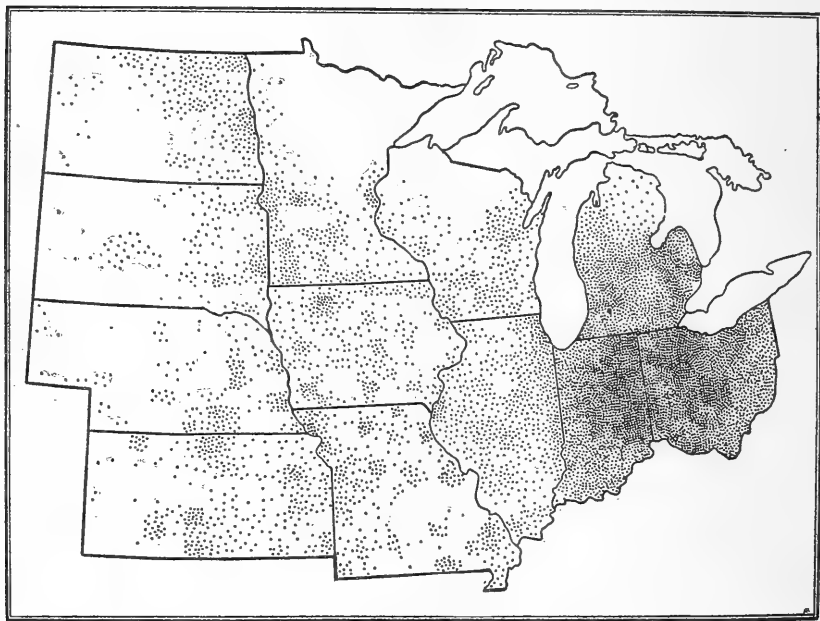


FIG. 2.—The distribution of wide woven wire.

lighter wires to keep down the cost. When the farmers of Area No. 1 began to use much woven wire the processes of manufacture had been so modified that the cost of the wire was much less and the higher fencing was being made.

WOODEN FENCES.

Much wooden fence is still in use in Ohio, Michigan, and Indiana (fig. 5). These States were originally heavily timbered and when the farms were cleared this timber was used to fence them. The best live, white, and bur oak, chestnut, and walnut was used to make rails, boards, and pickets, and the relatively high percentage of wooden fence still in use is the remnant of fences built by the early settlers.

They are not the original fences, however, but are made from the serviceable timber that has survived the numerous rebuildings. Rail fences are blown down by the wind when they are placed in unprotected places and they are sometimes pushed over by stock. They have to be rebuilt on an average of once every 12 to 15 years. Each time they are rebuilt some of the bad rails have to be discarded. The rails now in use are about worn out, and it will be a matter of but a short time when there will be no rail fences in use in these States. Both timber and labor are too expensive at the present time to permit making new rails. Rails that were split from 25 to 40 years ago cost then \$1.50 per hundred, and such of them as are still serviceable sell

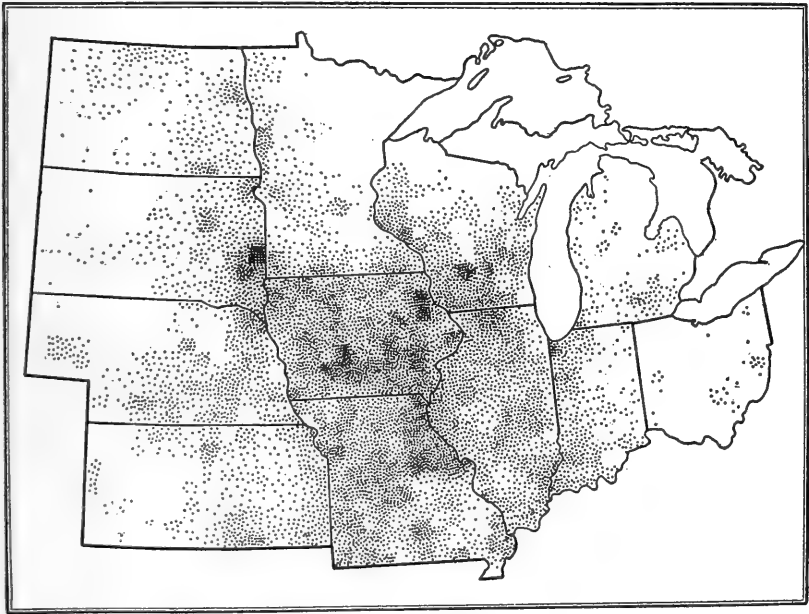


FIG. 3.—The distribution of narrow woven wire.

to-day for from \$2 to \$3 per hundred. Many old rail fences have brought enough for firewood to replace themselves with good woven wire.

The picket fence is a type which came into use following the worm rail. It made a good fence for all kinds of stock but like other types of wooden fence it has become obsolete with the diminishing timber supply and the introduction of wire fence. The picket fence is very expensive to keep in repair, as the pickets are heavy, especially when wet, and cause the fence to sag.

Board fences still remain in use to a limited extent. They are excellent for some purposes, as the protection of a barnyard from heavy winds. As commonly built, they are comparatively short lived,

and the cost of keeping them in repair is considerable. They are too expensive to be used for field fence.

HEDGE FENCES.

Hedge fences are most extensively used in the prairie regions of central latitudes, but they are scattered in small amounts over a considerable territory, as may be seen in figure 6. Practically all farm hedges in the North Central States are made from the Osage orange, or bois d'arc (wood of the bow). The home of the Osage orange is in Oklahoma and northeastern Texas. It is well adapted to conditions found in eastern Kansas and Nebraska and in southwestern

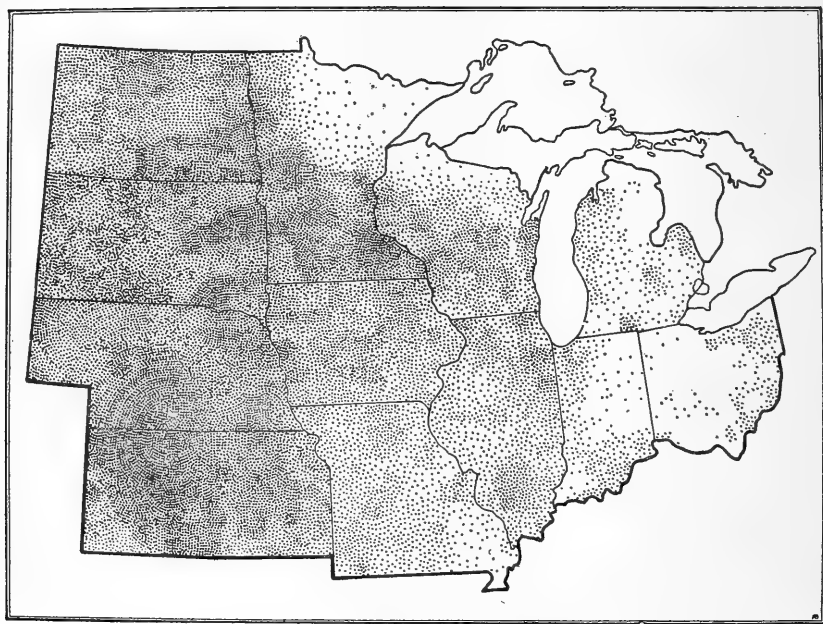


FIG. 4.—The distribution of barbed wire.

Missouri. As previously stated, when hedges were first established in the prairie country they were the most economical fence to be had. Wire fence was not in use at that time; timber was not available except when hauled for long distances, and transportation facilities were poor. Conditions have changed since that time, however, and the hedge fence is no longer desirable or economical. At best, hedge does not make a good fence. If swine are to be fenced, wire must be added in order to make it effective. Hedge plants are often killed by one cause or another and then there is a gap in the fence to be filled if it is to be stock proof. Even if the hedge is kept properly trimmed, it makes considerable land unfit for cultivation, and if it is not kept trimmed the amount of land it wastes increases in pro-

portion to the size of the hedge. The trimming is an expensive operation, and amounts to more than the cost of repair of wire fencing, as will be shown under another heading.

The idea of the hedge fence was brought to this country from England. English farmers were forced to use this means of inclosing their lands on account of the scarcity of timber in that country. This country was settled largely by English people, who clung to the customs of their mother country, and established hedges as a matter of custom, sometimes where the conditions did not warrant their use.

No new hedges are being established in the region here under consideration. Many farmers who have hedges now realize that they

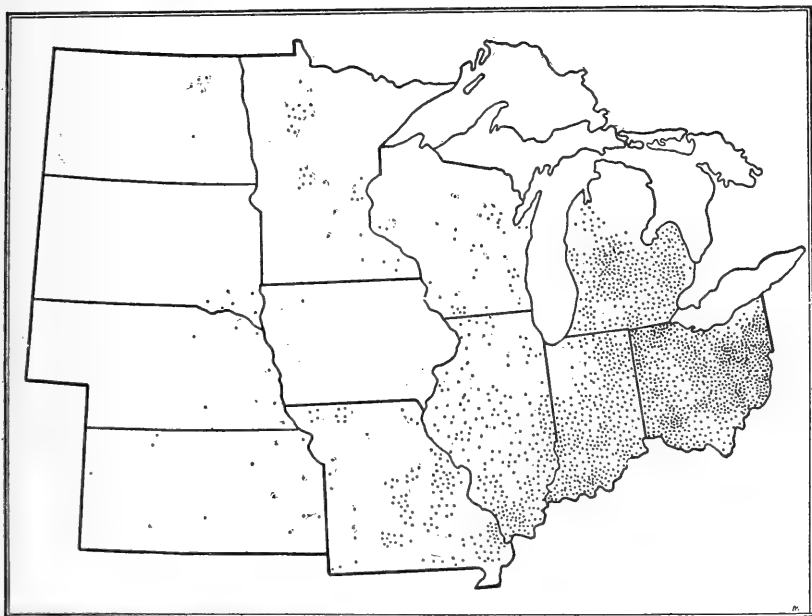


FIG. 5.—The distribution of wooden fence.

are no longer practicable and are removing them from their farms. The only feasible way to get rid of them is to pull them out by the roots. It costs about 30 cents per rod to draw out small hedge by team and from 20 to 25 cents per rod when an engine is used. It will, of course, cost more to remove larger hedge.

STONE FENCES.

There is comparatively little stone fence used on farms in the area studied. In the limestone area of eastern Kansas and in eastern Wisconsin there is some stone fence in use. Small amounts are found in other parts of the area, but not enough to show on the fence map (fig. 7.).

A stone wall when properly constructed makes a very satisfactory fence for all kinds of stock but sheep. They will climb over it unless a rail or wire is run over the top. Stone fences, if not well built with foundations of large stone, will be heaved by frost action. They also form a breeding place for brush and weeds, and harbor insects and burrowing animals. At the present time the labor cost of building a stone fence is so great that its construction is impracticable.

FACTORS INFLUENCING FENCE REQUIREMENTS.

The kind and amount of fence needed on a farm is regulated by the kind of farming practiced and the size of the farm.

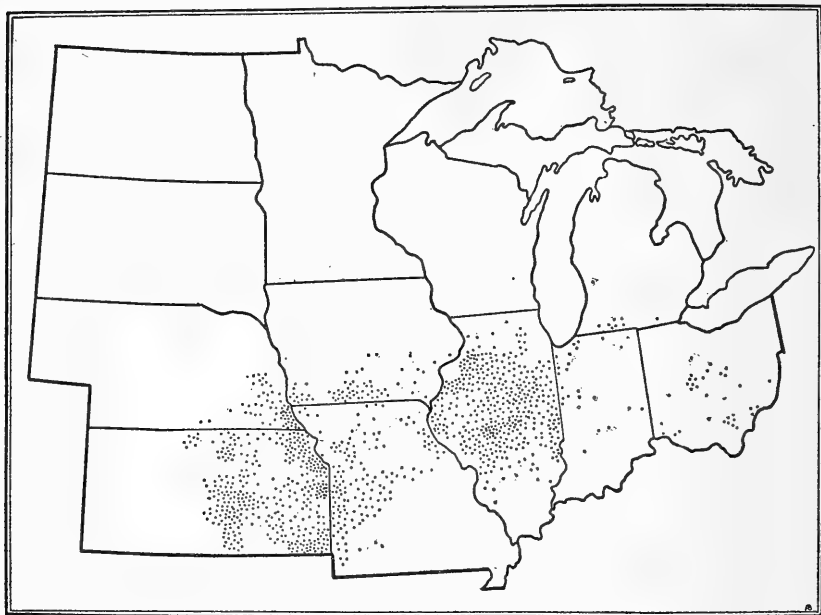


FIG. 6.—The distribution of hedge fence.

Tables 2 to 7 show the distribution of certain types of fencing in the areas where the farming and economic conditions made them the most desirable. The various types of fence do not in all cases best meet the present needs of the localities where they are used. In some instances the farming system has changed, and in others changing economic conditions have made certain kinds of fence obsolete.

A farm fence should combine the two qualities of service and economy. To give satisfactory service it must be constructed so as to turn all kinds of stock, and that without injuring them. To be economical it must be built as cheaply as is consistent with durability.

The fence that is erected at a low initial cost is not necessarily economical, for it may be short lived, which may make it very expensive.

A certain kind of fence may be economical when erected on one type of farm, but it may be very impracticable when used on another farm where conditions are different. For example, a general farm in Ohio and a cattle ranch in western Dakota may be compared. These two types represent widely varying conditions. The Ohio farm averages about 90 acres, of which 70 acres are in crops. Cattle, horses, swine, and sheep are pastured on this farm, and the entire farm is

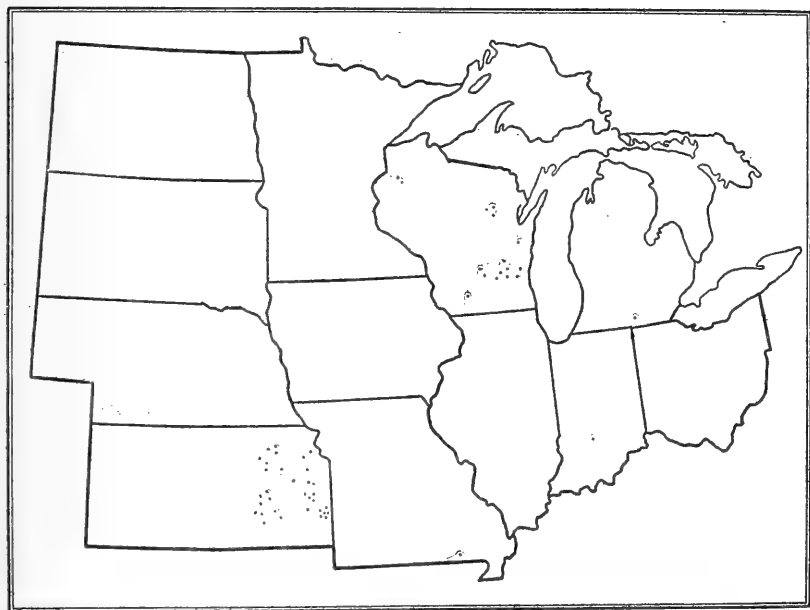


FIG. 7.—The distribution of stone fence.

often pastured at some time during the year. The fence, therefore, must be a general-purpose one and adequate to meet the varying requirements. Woven wire is best suited to such conditions. A barbed-wire fence when constructed so as to be adequate for all kinds of stock requires so many wires that its first cost is nearly equal to that of a good woven-wire fence. The cost of upkeep of a fence of this kind would be much greater than for one of woven wire. In addition, the danger of injury to stock from coming into contact with it is considerable. The farmers in Ohio have realized these things and have mostly abandoned the use of barbed wire.

Conditions in western Dakota are radically different. On the stock ranches here comparatively little land is in crops, while large acreages

are devoted to permanent pasture. The stock kept are mostly cattle, and they are kept on pasture much of the year. Barbed-wire fences sufficient to turn cattle can be much more cheaply constructed than woven-wire fences, and under the conditions prevailing here are nearly as satisfactory. Even if a few steers are lost as a result of wire cuts, their loss would go but a short way toward balancing the higher cost of building and maintaining woven-wire fences.

TABLE 2.—*Number of rods of fence per acre on farms of different sizes in the various areas studied.*

Acreage grouping.	Area No. 1.			Area No. 2.			Area No. 3.			Area No. 4.			Average.		
	Average acreage.	Number of farms reporting.	Rods of fence per acre.	Average acreage.	Number of farms reporting.	Rods of fence per acre.	Average acreage.	Number of farms reporting.	Rods of fence per acre.	Average acreage.	Number of farms reporting.	Rods of fence per acre.	Average acreage.	Number of farms reporting.	Rods per acre.
100 and under ..	77.0	565	8.0	79.3	232	7.4	79.3	51	7.5	.....	.....	.....	77.8	848	7.8
101 to 140..	123.2	361	6.9	123.8	199	6.3	126.1	67	6.2	.....	.....	.....	123.7	627	6.6
141 to 180..	160.2	363	6.3	161.1	330	5.7	163.3	346	6.0	160.1	114	4.7	161.4	1,153	5.8
181 to 240..	208.1	272	5.9	214.8	316	5.1	220.1	269	5.3	221.7	26	4.0	214.6	883	5.4
241 to 320..	280.3	167	5.0	289.7	194	4.6	301.2	309	4.8	315.3	131	3.4	296.4	801	4.5
321 to 400..	356.8	93	4.9	366.7	103	4.3	370.5	167	4.7	376.7	39	3.2	366.9	402	4.5
401 to 600..	490.5	76	4.8	480.3	107	4.4	498.8	221	4.2	499.4	108	2.7	493.8	512	4.0
601 to 1,000.	757.0	23	3.6	734.6	45	4.5	743.1	170	3.9	765.9	165	2.4	752.3	403	3.3
1,001 to 1,500.	1,170.6	10	4.5	1,210.8	7	2.8	1,247.4	42	3.5	1,186.6	53	1.9	1,209.6	112	2.8
1,501 and over.....	2,414.2	7	3.1	2,101.6	8	2.1	2,617.8	28	2.5	2,420.6	53	1.7	2,451.1	96	2.1

RELATION OF SIZE OF FARM AND TYPE OF FARMING TO RODS OF FENCE PER ACRE.

From an examination of Table 2 it will be seen that the amount of fence used per acre is considerably less in Area No. 4 than in the other areas. This is due to the fact that much less stock is carried in proportion to the size of the farms by the farms in Area No. 4. There are many purely grain farms in this area which carry no stock other than the necessary number of horses to do the farm work. Some of these farms have a pasture fenced for their horses, and the remainder of the farm is left unfenced.

Table 2 also shows that as the size of the farm increases the number of rods of fence per acre decreases. The smaller fence requirement of the large farm is due first to the fact that less fence per acre is required to inclose a large field than a small one; a square 10-acre field requires 16 rods of fence per acre, while a square field of only 1 acre requires approximately 50 rods; secondly, the crop rotation practiced on the small farm is usually similar to that of the large farm and requires as many fields, therefore proportionately much more division fence than is required by the large farm.

The fence requirement of two farms in the same locality may differ if the cropping systems followed on these farms are not similar. Factors influencing the amount of fence needed by the farm are the number and kind of stock kept, the pasturage customs, and, as already stated, the length of the rotation and the size of the farm. Many farms have fields which are not easily accessible or are too rough for cultivation, and such fields are often kept permanently in pasture. If all the stock on the farm is kept on this permanent pasture during the entire growing season, much less fence is required, there being no division fences necessary between the crop fields. On other farms the pasture forms a unit of the crop rotation, and on many farms having small acreages in permanent pasture it is supplemented by pasture in rotation. Often it is the custom to turn stock into the cultivated fields after the crops have been harvested in order that they may utilize such feed as is left on the ground after harvest. There are very few farms in Areas 1, 2, and 3 on which stock are confined entirely on permanent pastures during the entire pasturage season, and such a practice is not generally feasible. In order to utilize all farm land to its fullest extent in these areas it is necessary for the farm to be suitably fenced.

The field arrangement of the farm is a big factor in influencing the amount of fencing required on the farm. Field arrangement is governed by the natural topographic conditions of the land, the shape of the farm, the roads running through or around it, and the cropping system followed. When the farm is located in a hilly or rolling county it is quite essential that the field arrangement be such as to make it as easy as possible to work over the uneven land. In a level country the question of topography will not have to be considered. The cropping system and the shape of the farm will be considered jointly. The length of the rotation will determine the number of fields on the farm. If a three-year rotation is to be followed, three crop fields will be required; if a five-year rotation is to be practiced, provision will be made for five fields. The arrangement of these fields should conform to the shape of the farm in such a way as to make each field readily accessible to the buildings and to permit the farm work to be done with a minimum of travel. Also the layout of the farm should be such as to make the amount of fence required as small as possible and still retain the other essentials.

In much of the area covered by this investigation the land is divided into sections. Each section is a mile square and contains 640 acres. The highways follow along the section lines, and normally each section is entirely surrounded by roads. A farm must furnish the entire amount of road fence about it, but only half of any fence separating it from another farm. Hence the location of

roads along the farm boundaries will influence the amount of fence needed. Other things being equal, farms having the most frontage on public highways will require the most fence. The number and location of the roads surrounding a farm do much to determine the layout of the farm and consequently the amount of internal fence required. It is the common custom to place the farmstead adjacent to the main or most traveled highway.

The field arrangement depends on whether this main road runs along the long side or along the short side of the farm. Many times the farm is cut into two or more separate divisions by roads, but it is more common for it to be in one division. This is especially true of small farms.

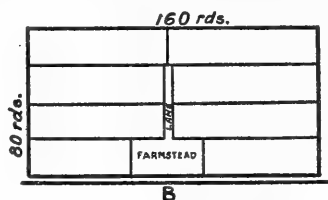
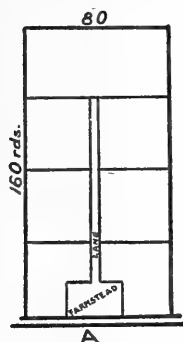


FIG. 8.

requires 120 rods more fence than A. In B the highway runs along the side of the farm, while in A it runs along the end.

The number and cost of farm gates is another item of considerable importance.

TABLE 3.—*Number of gates used on farms of varying sizes in Indiana, Michigan, Wisconsin, and Illinois.*

Acreage grouping.	Average acreage.	Number of farms reporting.	Number of gates.		Rods of fencing per gate.
			Per farm.	Per acre.	
100 and under.....	78.5	502	9.9	0.126	61.5
101 to 140.....	124.1	367	12.7	.102	64.6
141 to 180.....	166.0	512	14.3	.086	67.6
181 to 240.....	212.3	457	16.6	.078	69.3
241 to 320.....	286.3	276	19.2	.067	71.7
321 to 400.....	360.0	137	21.6	.06	75.1
401 to 600.....	479.4	138	29.2	.061	73.0
601 to 1,000.....	740.7	50	32.6	.044	110.3
1,001 to 1,500.....	1,151.3	12	52.9	.046	83.8
1,501 and over.....	2,047.1	13	40.9	.02	119.1
Total ...		2,464	.....	Average of all..	71.2

The larger farms not only require less fence to the acre but they also require fewer gates for a given amount of fence. There is an average of 1 gate to every 61.5 rods of fence on the smallest farms, as compared with 119.1 on the largest and 71.2 on all farms. The average value of gates is \$3.27 each. This makes an average cost of 0.045 cent per rod of fence for gates. The gates used on farms

vary greatly, both as to kind and cost of materials used and the manner of construction. It is not uncommon to find a gate, one that must be opened and closed many times every day, so made that it is a load for the average man to lift, and hung in such a way that every time it is opened and closed the operator has to drag it back and forth by main force. Gates of this kind have no place on any farm. They usually cost just as much as a gate that is so constructed and hung as to be easily handled. There are several types of automatic gates which may be opened and closed by pulling levers so placed that they may be reached by the driver without dismounting from the wagon seat. A gate

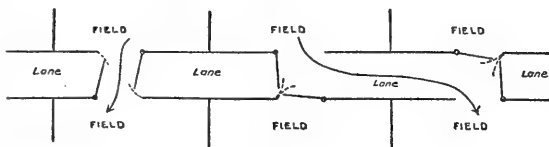


FIG. 9.

of this type is very convenient, especially when spirited horses are used on the farm. The arrangement of gates on the farm should be such as to make the fields as readily accessible as possible. In figure 9 is shown a gate arrangement along a farm lane which will allow of the running of stock from one field to another by simply fixing the gates so that they connect the desired fields. The lane is 12 feet wide and the gates 11 feet 9 inches long.

TABLE 4.—Distribution of fence on the farm and how it is effected by the size of farm.

Kind of fence.	Size of farms (acres).										Average.
	100 and under.	101 to 140.	141 to 180.	181 to 240.	241 to 320.	321 to 400.	401 to 600.	601 to 1,000.	1,001 to 1,500.	1,501 and over.	
	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>
Road.....	24.6	26.2	30.9	30.5	35.3	34.6	34.8	42.0	47.7	43.4	36.3
Line.....	25.7	26.1	23.2	23.9	22.3	23.4	23.4	20.6	18.0	20.8	22.3
Permanent inside.....	40.7	40.1	37.8	38.0	35.6	35.9	36.1	32.8	29.3	32.5	35.3
Temporary inside.....	1.0	1.1	1.5	1.3	1.5	1.0	1.1	.9	1.0	.7	1.2
Farmstead.....	8.0	6.5	6.4	6.2	5.4	5.1	4.6	3.6	3.9	2.6	4.9

DISTRIBUTION OF FENCE ON THE FARM.

In Table 4 the fences were divided into five general classes with reference to their location on the farm. The names of these classes—namely, road, line, permanent inside, temporary inside, and farmstead—are self-explanatory and denote the location of each on the farm. It may be noted that as the size of farm increases the proportionate amount of road fence increases, while the line or division fence decreases. The amount of permanent inside and farmstead fence is relatively smaller on the larger farms. It will be noticed

that permanent inside fence constitutes on an average 35.3 per cent of the total farm fence, and that there is but 1.2 per cent of temporary inside fence used. In many cases a considerable amount may be saved by the use of temporary instead of permanent interior fences. Figure 10 represents a farm of 160 acres which is fenced on the four sides with permanent fence. The farmstead and the lane are both inclosed by permanent fence. By eliminating the remaining interior fences there are 474 rods less fence to maintain. The annual cost of maintaining 474 rods of a fair grade of woven wire having an investment cost of 65 cents per rod and lasting 15 years is as follows:

Cost of repairs at \$0.024 per rod.....	\$11. 37
Interest on average investment (total investment \$308.10), \$154.05, at 5 per cent.....	7. 70
Depreciation, one-fifteenth of \$308.10.....	20. 54
Total.....	39. 61

To maintain the necessary amount of temporary fence would require a very small investment. Permanent and solid anchor posts should be placed along the lane and along the outside of the farm at the field divisions. This would require 14 anchor posts, 4 of which could be used in the permanent lane fence. They should not cost over \$4 each for material and labor. There would be no depreciation on posts of this kind if they are properly constructed. Enough wire would be needed to fence in any field on the farm. This would require not to exceed 160 rods of fence.

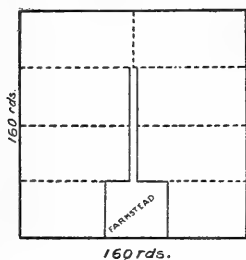


FIG. 10.

If the fence is taken up at the end of the season and stored, it will not be subjected to as much corrosion by weathering, but it would probably become unserviceable as soon as permanent fence on account of being handled and stretched so often. It would probably be more desirable to use medium-weight wire for this purpose on account of the greater difficulty of handling the heavy wire. If heavy anchor posts are provided, it will not be necessary to place the line posts closer than 2 rods apart, as the wire can be stretched very tightly and should not become loose enough in one season to permit stock to get through it. Only a fair grade of posts would be needed to last as long as the wire. Such posts should cost not to exceed 20 cents each, or 10 cents per rod. The largest item of expense would be the labor. This should not exceed 8 cents per rod. A glance at Table 8 (p. 30) would seem to indicate that this figure is liberal. The total approximate cost per rod of materials exclusive of anchor posts would be as follows: Woven wire, 28 cents; posts, 10 cents; barbed wire and staples, 4 cents; total, 42 cents per rod. Following is a summary of the cost of maintaining 160 rods of temporary fencing:

Interest on an investment of \$67.20 (average investment \$33.60) for fence materials, at 5 per cent.....	\$1. 68
Interest on an investment of \$56 for anchor posts at 5 per cent.....	2. 80
Depreciation, one-fifteenth of \$67.20.....	4. 48
Annual labor charge.....	12. 80
Total annual cost.....	21. 76

There is an annual saving of approximately \$18 by the use of temporary fence in this instance. While the practices on some farms may require more interior fencing than the amount cited in this instance, others will not require as much. Many times it will be desirable to pasture two or more fields at one time, and in such a case often only one cross fence will be needed. These figures refer to the construction of a temporary fence which is suitable to all kinds of stock. Often a far less expensive fence would answer the purpose where certain kinds of stock are to be pastured for short periods of time. The farmers in Iowa use a very inexpensive form of fence for hogging down corn. The fence is supported on a row of cornstalks which has had the ears removed and the stalks cut down to the height of the fence. The wire is woven in and out among the stalks so that four hills are on one side and four on the other, and so on. A fence of this kind requires no material for its construction other than the wire and end posts. It can also be quickly built. Besides the direct saving in the cost of maintaining the fences no land is lost to cultivation in the form of headlands along fence rows, and also there is no labor required to keep down weeds and brush that would otherwise accumulate along the fence row.

RELATION OF FIRST COST TO COST OF FENCE MAINTENANCE.

The cost of maintaining a farm fence is determined by five factors: Interest, repairs, and depreciation on the fence itself, interest on the value of the land rendered unusable, and the expense of keeping down weeds. The cost of repairs and the annual depreciation depend largely on the construction. If a fence is made from a cheap grade of material and is cheaply constructed, it will need frequent repair and will be short lived. Such a fence will have both a high repair and a high depreciation charge, which will in most cases more than counterbalance the increased investment cost that the erection of a more substantial fence would require. If a fence is made of good materials and is properly built, its repair and depreciation charges should be very low; but if the increased cost does not represent a corresponding increase in service the investment charge will be so much greater that the decrease in repair and depreciation charges will not counterbalance it.

The efficiency of the fence depends upon the quality of the wire and posts used and upon the manner of construction. Each of these factors will be considered in the order mentioned.

The first step in the construction of a fence is to select the kind best adapted to the purpose for which a fence is needed. The conditions to which the different types of fence are adapted have been briefly discussed under the heading, "Local requirements and adaptation," but it may be well to review and supplement them here. As there stated, barbed wire, when used to inclose extensive pastures and where only cattle are to be restrained, makes a satisfactory fence. Generally speaking, however, its use alone as a fencing material is not desirable. Woven-wire fencing is fast replacing the other types in use on the general farm where several kinds of stock are to be pastured. Fifty-one per cent of the total fencing used in the area covered by this study is woven wire, and the percentage is rapidly increasing. This woven-wire fencing is made up in many different styles as regards height, spacing of the wires, and size of wire. Each style is constructed so as to be adapted to meet certain conditions.

LIFE OF AND TEST FOR WIRE FENCING.

The cost and the life of the various styles of woven-wire fencing differ greatly. Many purchasers consider the first cost of the various kinds to such an extent that they lose sight of the difference in their length of service, which is the controlling factor of their ultimate cost. Table 5 has been computed from the experience of a large number of farmers with the use of the different styles of fencing and shows the relative durability of the different weights and heights of woven wire.

TABLE 5.—*Relative amount of service given by different weights of woven-wire fabric.*

Size of wire.	Number of estimates.	Average life.	Size of wire.	Number of estimates.	Average life.
		Years.			Years.
No. 9 throughout.....	637	21.1	No. 9 top and bottom, No. 11 laterals, No. 12 stays.....	53	17.7
No. 7 top, No. 9 bottom, laterals and stays No. 11 or No. 12.....	35	20.3	No. 10 top and bottom, No. 11 laterals and stays.....	23	16.7
No. 9 top and bottom, No. 10 laterals and stays.....	73	18.9	No. 11 top and bottom, No. 12 laterals and stays.....	43	14.6
No. 9 top and bottom, No. 11 laterals and stays.....	490	17.5	No. 12 top and bottom, No. 14 laterals and stays.....	46	12.7
No. 9 top and bottom, No. 12 laterals and stays.....	349	17.4			

Relative amount of service in years given by different widths of woven-wire fabric.

Height of fence, inches	26	32	36	39	42	47	55
Number of estimates	206	214	19	247	42	865	156
Life of wire, years	17.2	17	18.3	18.8	19.9	18.9	21.7

It is becoming generally recognized that the heavier styles of woven-wire fencing are more economical to use. The initial cost of the heavy wire is greater, but it lasts more than enough longer to offset the additional cost. It costs practically as much to con-

struct a fence in which a light grade of woven wire is used as to build one of heavier wire; and as the heavy material lasts much longer the cost of construction is distributed over a longer time, hence it is less per year. During the life of the two types of fence the repair costs of the heavier fencing are less. The percentage of heavy wire manufactured and sold for fencing purposes has greatly increased in the last five years. The use of the wider styles of woven wire has also become more general. The narrower types were first made, as previously mentioned, on account of the excessive cost of materials. It has been the experience of farmers that they are more expensive to maintain, as stock get their heads under the barbed wires and crowd down the woven-wire fence. This is especially true where large hogs come into contact with these fences. Table 5 shows the higher fence has the longer life.

In order to reduce the first cost of a fence, it has been the common practice to buy a woven-wire fabric of smaller-sized wire. By doing this the purchaser is reducing the weight of material, and consequently the initial cost; but in doing it he is practicing false economy. In many cases, however, the first cost of the fence can be materially lessened by eliminating unnecessary material from the fence in the shape of wires that are not needed; for example, when cattle, sheep, or horses are to be fenced against it is not necessary to have a fence with such close spacing as is required when swine are to be turned. The common general-purpose fence in use is one having approximately 10 line wires and a total height of approximately 4 feet; the bottom wires are spaced about 3 inches apart. Such a fence is admirably suited to general purposes where both large and small stock are to be fenced in, but it is not essential to the farmer who keeps either cattle, horses, or sheep, and no swine. A woven fence with fewer wires and wider spacings will serve to turn cattle, horses, and sheep, and such a fence can be erected at considerably less expense, due to the fact that there is less material in it. Woven-wire fencing is made in numerous styles which are adapted to use under widely varying conditions, so it should not be difficult for the farmer to secure a style of fence adapted to his needs.

In the purchase of wire fencing it must be borne in mind that one of the dominant factors controlling the cost of the fencing is the weight of wire in it. This depends on the spacing of the wires and their size. The most accurate means by which the farmer may compare two different lots of wire fencing of the same style is to weigh them. Fencing containing undergauged wire will of course be lighter than fencing which is made from full-gauged wire, provided the spacing of the wires is the same in each case. Wire fencing should be sold by weight rather than by the rod. To a great extent the durability of the fence depends upon the size of wires used in its make-up. The number of wires used will depend upon the purpose for which the fence is to be used.

The chemical and physical properties of the wire and also the amount of galvanizing carried by it are factors in determining its durability. It is not the purpose of this publication to go into the details of the manufacture of the steel, as these are very exhaustively treated in Farmers' Bulletin No. 239 of the United States Department of Agriculture. It may be well, however, to mention the processes commonly used in the manufacture of steel wire. The steel from which most of the wire fencing is made at the present time is manufactured by two processes, the Bessemer and the basic open hearth. Formerly steel for wire was made by what was called the puddled-iron process. This process involved the working of the steel by hand labor, which was necessarily slow and expensive, and upon the introduction of the Bessemer and open-hearth processes it was abandoned, as steel could be made by these processes so much more cheaply. It is generally believed that the steel made from the puddled-iron process was superior to that made by the Bessemer and open-hearth processes for the manufacture of wire fencing. Farmers point to the fact that the first woven-wire fences gave them better service than those of the present day. It is, however, impracticable to make wire from steel manufactured by the puddled-iron process, and the manufacturer of wire fencing of the present day improves his product by increasing the quality and quantity of galvanizing. People have come to realize that the amount of galvanizing carried by the wire greatly affects its life and demand fencing with a heavy coating of it. The relative amount of galvanizing or spelter on a wire may be determined by testing the wire in a solution of copper sulphate.

TEST FOR WIRE FENCING.

The common test applied to determine the relative amount of spelter carried by a woven-wire fabric is as follows: A saturated solution of copper sulphate is made by dissolving 36 parts of copper sulphate to 100 parts of water by weight. Not less than a quart of the solution should be used in the test, and to make a quart of the saturated solution requires approximately $11\frac{1}{2}$ ounces of copper sulphate, or, as it is commonly called, blue vitriol. Slightly more than this amount should be used, however, as there should be a small excess of the copper sulphate. This may be either left in the solution or the solution may be strained off from it. The wire to be tested is immersed in the prepared solution, which should be at a temperature of 60 to 70° F., and left for one minute, at the end of which time it should be removed and wiped thoroughly dry. This operation should be repeated until the wire shows a deposit of metallic copper. The copper will not be deposited on the wire until the galvanizing is removed and a well-galvanized wire should stand at least three immersions in the copper sulphate solution without showing copper deposits on it. Some specially galvanized wire will withstand four immersions without showing copper. This wire is

known as four-minute wire, and may be had at a slight advance in price. When the common commercial copper sulphate is used in performing the test, there is a very slight excess of acid present in the copper sulphate solution which, if not neutralized, may cause the solution to act more strongly on the wire than it should. The acidity may be neutralized by adding a small amount of copper oxide; 2 ounces to a quart of solution should be sufficient. On account of the nonsolubility of the copper oxide it must be added a long time, at least a month, prior to the time the solution is to be used.

POSTS: LIFE, COST, PRESERVATION, AND MATERIALS.

In the construction of a fence the question of the selection of posts is a very important one. The cheapest post to use will vary with the conditions found in the locality where the fence is to be built. The kinds of native timber and their costs must be considered. It is not advisable to construct a permanent wire fence on posts that will not last as long as the wire. When this is done the fence has to be re-stretched on a new set of posts, the cost of repairs will be considerably increased, and the full efficiency will not be gotten from the wire.

Table 6 shows the average life of the different kinds of fence posts in use in the localities studied, and the cost of these in the different areas. Upon examination of the table it will be noted that the ratio of cost to life is approximately 1 cent per year for most kinds of posts. These figures represent the life of fence posts of approximately 4 inches in diameter, under average conditions. There are many factors influencing the life of a fence post, and these factors have not been considered in this table. The size of posts, the amount of seasoning they receive before being set in the ground, the quality of timber from which they are cut, the kind of soil, the climatic conditions to which they are subjected, and the kind of stock that are to be fenced against, all influence the life of the post. The figures in this table serve to compare one kind of wood with another as to their relative value for fencing purposes. It is shown that Osage orange, locust, red cedar, mulberry, and bur oak are the only kinds of timber that last on an average of more than 15 years when used for fence posts. The supply of practically all of these timbers is limited, and most of them are relatively high priced, especially in areas where they are not native. Osage orange posts are to be obtained commercially in only a small area of the country. This timber is native to northeastern Texas and Oklahoma. There has been much Osage orange hedge built in the past, and many of these hedges have been allowed to grow up into trees and posts have been cut from them. However, this practice is not a profitable one on high-priced land, as the hedge row consumes fertility from too much land which would otherwise go to crop production. The supply of locust timber has been affected by the depredations of the locust borer, and is constantly decreasing, while the price of this timber is increasing. Most of the

red cedar posts which are used in the corn belt area have to be shipped from the Southern States, and their cost to the farmer is steadily advancing. To sum up the fence-post situation, it would seem that the decrease in the supply of timber suitable for use as posts and the increase in cost of this timber to the farmer will in the near future make it advisable to use a substitute for wooden posts or to treat the cheaper woods with a preservative material that will serve to prolong their life.

TABLE 6.—Average cost by areas and the average life of various kinds of fence posts.

Kind of post.	Average life.		Average cost in all areas.		Average cost in each area.							
					Area No. 1.		Area No. 2.		Area No. 3.		Area No. 4.	
	Number estimated.	Years.	Number estimated.	Cents.	Number estimated.	Cents.	Number estimated.	Cents.	Number estimated.	Cents.	Number estimated.	Cents.
Osage orange.....	789	29.9	774	22	105	25	326	24	320	17	23	18
Locust.....	464	23.8	465	24	501	26	21	22	23	18	14	18
Red cedar.....	557	20.5	574	29	346	29	97	31	104	27	27	21
Mulberry.....	88	17.4	82	19	45	20	25	17	12	15	.....	.....
Catalpa.....	48	15.5	45	17	15	17	17	17	13	18	10	18
Bur oak.....	97	15.3	90	15	10	16	54	15	26	15	.....	.....
Chestnut.....	94	14.8	91	15	91	15	.....	.....	.....	.....	.....	.....
White cedar.....	1,749	14.3	1,709	18	642	18	459	18	374	19	274	16
Walnut.....	60	11.5	56	13	6	15	11	13	39	12	.....	.....
White oak.....	1,242	11.4	1,218	12	333	14	389	11	421	12	75	13
Pine.....	41	11.2	37	18	12	23	7	22	3	11	15	12
Tamarack.....	67	10.5	64	9	6	16	26	8	7	9	25	9
Cherry.....	9	10.3	9	8	7	8	2	8	.....	.....	.....	.....
Hemlock.....	10	9.1	9	12	3	20	6	8	.....	.....	.....	.....
Sassafras.....	19	8.9	17	14	11	15	6	10	.....	.....	.....	.....
Elm.....	15	8.8	15	12	6	10	5	9	4	15	.....	.....
Ash.....	69	8.6	58	10	17	11	2	10	15	10	24	10
Red oak.....	22	7.0	24	7	6	7	10	8	8	4	.....	.....
Willow.....	41	6.2	33	7	1	12	2	7	25	7	5	9
Concrete (estimated)	42	48.0	121	30	53	30	48	29	19	31	1	35
Stone.....	11	36.3	15	35	.....	.....	.....	.....	4	38	11	35
Steel (estimated)	131	29.9	219	30	82	30	71	29	54	30	3	30

PRESERVATION OF FENCE POSTS WITH CREOSOTE.

Decay of wood is brought about by the presence of fungi which live on the tissues of the wood. For the development and growth of these fungi certain conditions are necessary. Their growth requires heat, air, moisture, and a supply of food. It will be noticed that in the rotting of a fence post that part of the post which is at the ground line and just below the surface of the ground is the most affected. This is due to the fact that at this point all conditions are favorable for fungus growth. There is an abundance of air, moisture, and heat. In order to prevent decay it is necessary to remove one or more of the conditions necessary to the fungus growth.

The purpose of treating timber is to remove the conditions favorable to the growth of the fungi which cause decay. The moisture content of the timber may be reduced by placing a waterproof coating over it. Many experiments have been carried on, both by the Forest

Service of the United States Department of Agriculture and by various State experiment stations, with a view to determining the best preservative materials and the effect of the treatment of post timbers with them. It has been found that creosote, a by-product in the manufacture of coal tar, is the cheapest and most efficient preservative, and that naturally short-lived timbers treated with it will withstand decay as long as the most durable woods.

In many localities there is an abundant supply of cheap timber which in its natural state is of little value for fence posts, but which may be treated with a preservative so that its life will be greatly prolonged.

The treatment is very simple, and can easily be done on the farm. The equipment necessary for the work is not expensive, but depends to some extent on the number of posts to be treated and the amount of time available for this work. If it is the intention to treat a few posts at a time, only one tank will be needed.

The posts that are to be treated should be thoroughly seasoned and the bark should be removed from them so that the preservative will be able to penetrate into them. A good time of the year to cut them is in the spring after the buds begin to swell. They will peel very readily at this time, and should season in time for treatment in the late summer or early fall. After the posts are cut and peeled it is well to place them in piles so that the air will circulate through them, but so that they will not season so rapidly as to check.

The method of treatment depends somewhat on the number of posts that are to be treated and the time available for this work. The posts are first placed in a tank of creosote which has been heated to a temperature of about 220° F. They are left in this tank until the creosote has penetrated through the sapwood of the post. The time required to accomplish this depends upon the kind of timber being treated. Soft woods will be more readily penetrated and absorb more creosote. When the post has been in the hot creosote the desired length of time it is then placed in a cold creosote bath, where it should be left for several hours. While in the hot creosote the fibers of the wood expand and force out the air and moisture present. When placed in the cold creosote they contract and form a partial vacuum, thus drawing a quantity of the preservative into the wood cells. If only a limited number of posts are to be treated, or if it is not necessary to complete the work in a short time, the posts may be left in the tank of hot creosote until after it has cooled. If this method is employed, at the most, only two batches may be treated in a day. If many posts are to be treated, it is necessary to have an additional tank for cold creosote. The posts may be taken from the tank of hot creosote and immediately dipped in the cold. This permits a continuous process to be carried on.

The equipment necessary for the first process is a single tank which is large enough in diameter to hold the number of posts it is desired to treat at a time, and it must be high enough to support the posts and to allow the creosote to stand about 6 inches above the mark that will represent the ground line on the post when set. The creosote in the tank may be heated by several different methods—by placing the tank over a fireplace so that a fire may be built directly under it, by attaching a U-shaped pipe to the lower side of the tank so that a fire may be built under the pipe, or by placing steam coils in the tank in such a manner that they will not be in the way of the posts. The cost of the equipment will vary, but should be very small. Maryland Station Bulletin No. 163 estimates that the cost of the double-tank equipment should not exceed \$50. It should cost but a small part of this amount to equip a single tank capable of treating two lots of posts each day.

The cost of treatment will vary with the kind of wood used. It has been found that it does not pay to treat a naturally durable wood, because its fibers are so hard to penetrate with the preservative that the operation is a very expensive one, and after treatment a wood of this type is of no more value than a cheaper wood properly treated. Experiments have shown that beech, birch, gums, soft maple, poplar, sycamore, willow, and pin oak respond very readily to treatment. The cost of treating these timbers is approximately 10 cents per post. Creosote may be had in the Central States area for approximately 15 cents per gallon. It may be obtained from hardware dealers.

There is a large area of country, however, where even cheap timber is not to be had. In these localities the fence builder is wholly dependent upon the commercial supply of posts. The increased cost of wooden posts has brought substitutes upon the market in the form of steel and concrete. Posts of these types are coming into extensive use in certain areas and will no doubt be used in far greater numbers in the near future. Table 6 gives the estimated life of both steel and concrete posts, but it must be borne in mind that these figures are only estimates, as neither steel nor concrete posts have been in use long enough to determine their actual life. The estimate of 48 years of life for concrete doubtless does not take into consideration the number of posts that are broken off by accident and otherwise. Whether or not it is advisable to use either wooden, steel, or concrete fence posts will depend to a great extent on local costs of these materials. Until more is known of the service to be had from steel or concrete posts it will not be possible to compare their relative value with the more serviceable types of wood. It may be well to mention a few of the qualities of steel and concrete posts which commend their use.

STEEL POSTS.

Among the qualities possessed by steel posts the one that perhaps appeals to the average fence builder with greatest force is the fact that they are so easily handled, and that fences may be erected in a much shorter time when they are used. Where conditions are right for driving posts, two men should be able to drive 500 steel posts in a day. These posts do not heave, as more bulky ones often do. It is claimed that they form a protection for stock in that they ground currents of electricity carried by the fence during electric storms. For this same reason they should prolong the life of the fence, as the disintegration of wire is partially brought about through electrolytic action. The unfavorable criticism of steel posts is that they are bent by heavy stock rubbing against them. This may be avoided in two ways: First, if the fence is properly constructed, it should be tight enough that when pressure is brought to bear on the fence the strain will be transmitted to the end posts and the intermediate line posts, and thus not brought to bear on any one post alone; second, by the use of heavier posts.

CONCRETE POSTS.

The one point in the concrete post that appeals to the fence builder is its supposed durability. To secure a durable concrete post much care must be exercised in the selection of materials and in the construction of the post. Gravel or crushed rock should be used which does not exceed one-half inch or run under one-fourth inch in diameter. The sand used should be clean and sharp. To secure the best results a very rich mixture must be made and should run 1 part cement, 2 parts sand, and 3 parts gravel. It does not pay to stint the quantity of cement used, for a very slight reduction in cost caused by the use of less cement will make a very big difference in the quality of the post. It is important that the mixing of the materials be done very thoroughly. The reinforcement should be placed near the surface of the post, but not nearer than three-fourths of an inch. There should be enough reinforcing wires so that when a force is applied to the post from any direction at least one wire will be in tension. It has been found that when smooth cold-drawn wire is used for reinforcement purposes, the bond between the wire and the concrete is not strong enough; when a strain is placed on the post such a wire will slip in the concrete. This may be overcome by cleaning the wire with a strong caustic solution and washing with water, or the same result may be gotten by slightly rusting the wires with a diluted solution of sal ammoniac. Homemade wooden forms may be used in the construction of the posts, but better results can be obtained by the use of steel forms. Whether steel or wooden forms are used they should be thoroughly cleaned and oiled before using. The best time to clean the molds is just after the green posts are removed from them and before there is time for particles of concrete

to harden on them. The forms should be oiled before putting in the concrete, so that the surface of the posts when set will have a smooth appearance. A small amount of machine oil applied with a brush will answer the purpose. The concrete should contain enough water so that it may be poured, but not more than this. After being poured into the molds it should be jarred or vibrated so that it will settle and force out any air it may contain. This is essential to the making of a strong, smooth post. Ordinarily the posts can be removed from the mold at the end of 24 hours, but they have to be handled very carefully at this time. They then should be laid on a smooth floor and kept covered for a week or 10 days. During this time they should be sprinkled with water daily to prevent them drying out too rapidly while seasoning. At the end of a week or 10 days they may be stacked on end in piles. They should not be used for at least a month, and it is much better not to use them for three months, as they gain greatly in strength during this time.

In handling a well-seasoned concrete post care must be used not to jar it more than is absolutely necessary. Owing to the excessive weight of concrete posts it is very doubtful if fencing can be erected as quickly with them as with wooden posts. They must also be handled more carefully. They should be well set in the ground to prevent heaving. Should the post heave so as to lean over, its weight will tend to pull the fence down.

Extensive experiments have been carried on at the State college at Ames, Iowa, with the construction of concrete fence posts. In these experiments the cost of the cement used per post varied from 4 to 8 cents, and the cost of reinforcing rods from 9 to 12 cents per post. On farms where sand and gravel are to be had, and where the work may be done at a season of the year when the time might not otherwise be profitably employed, the construction of concrete fence posts is quite feasible. If the work is to be done in winter the concrete must not be allowed to freeze.

CONSTRUCTION OF WIRE FENCES.

The manner in which the fence is erected has much to do with the service to be gotten out of it. No matter how good the wire and posts, if the fence is not properly constructed it will be a very poor one. The cost of erecting a fence is such a small part of the first cost of it that this work should always be well done, yet it is no exaggeration to say that 50 per cent of the wire fences in use are not properly constructed.

The ends and corners are by far the most important elements of a fence. It is absolutely essential that they remain firm and solid in order to hold the fence rigid. In building a fence, therefore, the first thing to consider is the placement of the corner. There are several types of end and corner bracing systems in use any of which if properly installed will hold a fence solid. Plate II illustrates a

few of the more common types in use. Points to be borne in mind when setting wooden end or corner posts are: First, the posts used should be large enough to give sufficient strength. Second, they should be set deep enough not to heave by the action of frost. Wooden end or corner posts should be put into the ground to the depth of $4\frac{1}{2}$ feet, and the brace post should be set 4 feet deep. Third, the brace post should not be set so close to the end post as to require the placing of the brace at an abrupt incline, for this tends to force the end post out of the ground (it is generally considered that 10 feet apart is about the right distance). This arrangement would require a brace 12 feet long, and it is usually inserted in a mortise on the brace post 12 inches from the ground line. The brace should be large enough to remain perfectly rigid.

The manufacturers of steel posts issue instructions regarding the placement of their end and corner posts. These posts are set in concrete, and if properly placed are very solid.

Concrete end and corner posts are made in various styles and shapes. It is essential that they be made of a good grade of concrete and thoroughly reinforced. They may be reinforced with scrap iron, such as wagon tires, axles, etc., and the reinforcement should be placed so that the strain caused from the pull of the fence will bear against it. These posts should be allowed time to season thoroughly before the fence is attached to them.

End, corner, and line posts should be placed so that the ground will have time to settle and harden around them before the fence is strung. It is more essential that the end and corner posts be placed sometime previous to the stringing of the wire. The best time of the year to set posts is in the spring after the frost is out and when the ground is soft. It will thoroughly settle soon after the frost leaves and will leave the posts solid. The wire can then be strung whenever there is time for this work. Whether the posts are set or driven they should be kept in a straight line with the ends of the fence. If there is a curve in the fence the posts may be set so as to make a slight angle, and the post at the apex of the angle should be thoroughly braced in both directions. When steel posts are used they may follow the line of the curve, but in such a case they should be set in concrete and be anchored against the direction of the pull on the fence by using a brace set in concrete, or by the use of a deadman. When the fence is being built over a hilly country, or where there are depressions in the fence row, the posts that are placed in the depressions should be anchored down so that the upward pull of the fence will not tend to draw them out of the ground. This may be accomplished by spiking 2 by 4 crosspieces on the bottoms of the wooden posts before settling them in the ground. If steel posts are used they may be set in concrete.

The distance apart line posts should be set depends on the location of the fence and the number and kinds of stock to be turned. The

average distance in field fence is approximately 20 feet. Around barn lots and pens, where stock are in closer contact with the fence, they are set closer together. Many farmers set posts 1 rod apart. This arrangement is a very handy one in that it furnishes a quick means of measuring portions of a field. It is useful in checking up the amount of work accomplished daily in doing field work. The proper distance to set posts for the greatest efficiency with greatest economy is a matter requiring good judgment on the part of the farmer, for there are many factors involved.

In order to construct woven-wire fencing properly certain tools are necessary. These consist of a woven-wire stretcher, a single-wire stretcher to be used in attaching the fence to the end posts, a pair of wire cutters, a barbed-wire stretcher, a splicing tool, and hammers for stapling and fastening the fence. Some device should be used to unroll the barbed and woven wire. This may be done by attaching the roll of wire to the back of a wagon so that it will unreel as the wagon is drawn ahead, as shown in the illustration (Pl. III, fig. 2), or it can be unreeled by running a bar through the core and drawing it along with a horse. Before the wire is stretched the fence row should be freed from obstructions, and ridges and uneven surfaces should be smoothed off so the fence will be straight on the ground. The wire should be securely attached to one of the end posts and then unreeled. If there is not wire enough in the roll to cover the length of the stretch to be fenced, more may be spliced on to it in the manner shown in Plate III, figure 1.

After the wire is unrolled it should be drawn up to the line of posts and freed from adhering trash. The stretchers are then attached, leaving plenty of chain to draw up the slack in the wire. The stretching should be continued until the line wires are so taut that they can not be pressed together by the hand. If the ground is uneven, the fence should not be stretched so tight that the wire can not be drawn to its proper height on the posts. After the fence is stretched it should be securely fastened to the corner toward which it is being stretched. The next step is to fasten the wire on the line posts. In doing this the line wires should be kept as nearly horizontal as possible. They should not be allowed to follow small irregularities in the ground line and thus zigzag up and down from post to post. The fabric should not be fastened tightly to each post; the staples or ties should permit horizontal movement of the wire. This will allow the weight of the fence to come directly on the corner posts, and will take care of the contraction and expansion of the wire caused by varying weather conditions; also if a blow is delivered against the fence it will not be borne alone by the fabric and posts at the point struck, but the force of it will be distributed along the entire fence line. The barbed wire should be stretched and fastened after the fabric has been fastened in place. It should be placed about 4 inches above



FM6846



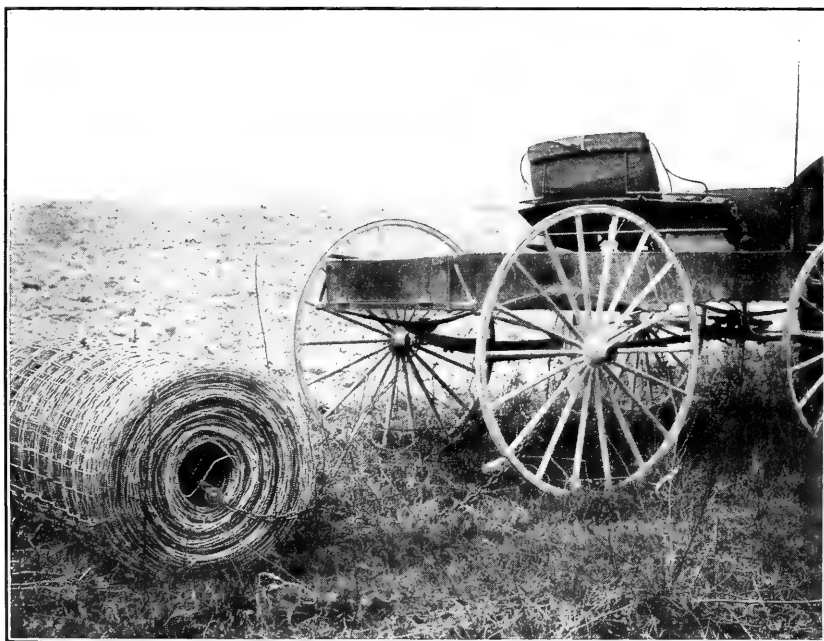
FM7029

DESIRABLE TYPES OF BRACES FOR ENDS AND CORNERS.



FM7026

FIG. 1.—SPlicing WIRE.



FM7027

FIG. 2.—UNREELING WOVEN WIRE.



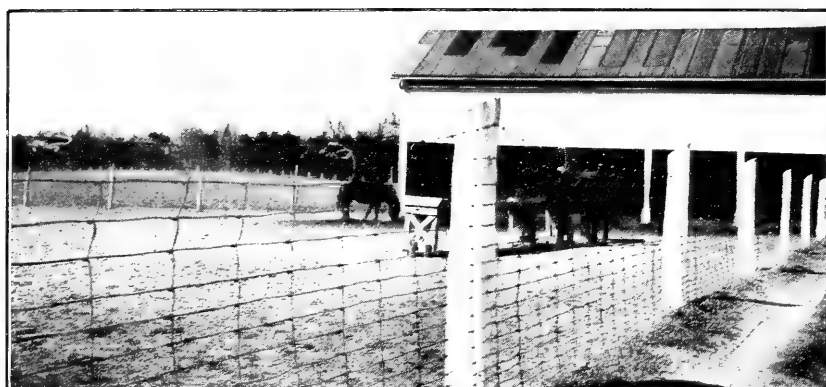
FM7025

FIG. 1.—STRETCHING WOVEN WIRE.



FM7010

FIG. 2.— ATTACHING THE WIRE AFTER IT HAS BEEN STRETCHED.



FM6827

FIG. 1.—A STRAND OF BARBED WIRE SHOULD BE PLACED ABOVE THE WOVEN FABRIC TO PREVENT HORSES AND CATTLE FROM REACHING OVER AND CROWDING DOWN THE WOVEN WIRE.



FM7023

FIG. 2.—TRIMMED HEDGES MAKE UNTILLABLE CONSIDERABLE LAND; UNTRIMMED HEDGE ROWS OFTEN OCCUPY A ROD OF GROUND ON EITHER SIDE OF THEM.



FM6850

FIG. 3.—THE RAIL FENCE OCCUPIES MUCH LAND ON EITHER SIDE OF IT WHICH CAN

the top of the woven wire so that stock will not be able to get their heads between it and the woven wire. A woven wire fence is not complete without the strand of barbed wire above it; this protects the woven wire by preventing stock from reaching over and crowding it down.

TABLE 7.—Amount of fence that two men can build in a day, both when setting the posts and when driving them, and when they are spaced at various distances; also the labor cost in cents per rod with wages at \$1.50 per day.

Kind of fence.	Day's work.				Labor cost per rod.				Number of fences on which estimates are based.			
	12 foot or less. ¹	13 to 16½ feet. ¹	17 to 24 feet. ¹	25 to 37 feet. ¹	12 foot or less. ¹	13 to 16½ feet. ¹	17 to 24 feet. ¹	25 to 37 feet. ¹	12 foot or less. ¹	13 to 16½ feet. ¹	17 to 24 feet. ¹	25 to 37 feet. ¹
Barbed wire:												
2 strands—												
Posts driven.....		Rods. 89.5	Rods. 95.0	Rods. 166.9		Cts. 3.4	Cts. 3.2	Cts. 1.8				
Posts set.....	58.7	71.5	75.0	121.5	5.1	4.2	4.0	2.5	8	19	9	11
3 strands—												
Posts driven.....	64.0	89.1	116.4	156.0	4.7	3.4	2.6	1.9	78	160	42	23
Posts set.....	43.7	58.7	68.3	95.4	6.9	5.1	4.4	3.1	101	433	136	102
4 strands—												
Posts driven.....	76.6	83.2	92.4	95.0	3.9	3.6	3.2	3.1	31	66	8	3
Posts set.....	39.3	47.9	50.6	70.8	7.6	6.3	5.9	4.2	117	315	64	24
5 strands—												
Posts driven.....	52.2	56.7	70.9	100.0	5.7	5.3	3.8	3.0	16	18	5	1
Posts set.....	25.3	34.1	38.7	46.2	11.8	8.8	7.7	6.5	33	69	16	4
6 strands—												
Posts driven.....	29.5	56.7	67.5	.....	10.2	5.3	4.4	.....	10	7	8	.....
Posts set.....	19.4	26.4	32.0	34.1	15.4	11.3	9.4	8.8	47	128	62	42
Narrow woven wire with 2 or more barbed wires:												
Posts driven.....	48.7	53.0	74.1	89.8	6.2	5.7	4.0	3.3	122	343	78	48
Posts set.....	26.3	33.0	37.9	47.1	11.4	9.1	7.9	5.5	440	1,482	535	338
Wide woven wire with 1 barbed wire:												
Posts driven.....	50.9	55.3	77.2	94.2	5.9	5.4	3.9	3.2	114	329	77	50
Posts set.....	27.2	33.9	39.9	49.7	11.0	8.8	7.5	4.6	430	1,410	539	332
Wide woven wire without barbed wire:												
Posts driven.....	61.3	65.4	80.2	108.5	4.9	4.6	3.7	2.8	105	311	52	40
Posts set.....	30.6	39.0	45.8	56.7	9.8	7.7	6.6	5.3	396	1,270	455	287

¹ Distance apart of posts.

The number of rods of fence that can be constructed in a day varies with soil conditions, the depth to which posts are set or driven, the ability of the men doing the work, the topography of the ground, and the distance apart of corner, end, and gate posts. Table 7 shows the amount of fence that two men can build in a day under average conditions. The posts are set at an average depth of 32 inches and the corner and end posts are placed approximately 40 rods apart. With long, straight stretches of fencing and with other conditions favorable, two men could build more fence than the figures in the table indicate. On the other hand, if the fence is to be constructed over rough and uneven ground and on a soil where it is difficult to set the posts or dig the post holes, or if only short lengths of fencing are to be erected, two men would not be able to build the amount of fence indicated in the tables. The figures indicate the amount of fence that may be erected in a day when the material is on the ground, and do not include the cost of hauling.

COST OF MAINTENANCE OF FARM FENCES.

As stated on a previous page, the cost of maintaining farm fences consists of (1) the interest charge on the money invested, (2) the annual depreciation charges, (3) repairs, (4) interest on the value of the land which is covered by fence rows and from which the farmer derives comparatively little or in some cases no benefit, and (5) the expense of keeping down weeds.

The interest charge is usually reckoned on the prevailing rate of interest on half the cost of a new fence, or it may be reckoned on the average present value of the fences on the farm.

The depreciation charge is determined wholly by the life of the fence. If this is 20 years, the annual depreciation charge would be one-twentieth of the first cost of the fence.

COST OF REPAIRS.

The repair charge will vary with the kind of fences used. The two most important factors influencing them are the quality of the fence and the use to which it is subjected. If the fence is built from good materials and is well constructed, the annual repair bill will be greatly lessened. A fence placed around a stockyard or pasture field will be subjected to harder treatment than one around fields where stock seldom reach it. Also, certain kinds of stock and some individual animals are harder on a fence than others. The repair charges on a fence are light during the early life of the fence, and increase as the fence grows older. There is, however, one item of expense which has to be considered as much with a new as an old fence. This is the cleaning up of the fence row and keeping it free from grass, weeds, and brush. It is estimated that the cost of keeping fence rows free from weeds, etc., amounts to 1 per cent per rod per year.

Table 8 has been computed from a large number of estimates furnished by farmers in the Central States. The figures show that wire fences are by far the cheapest to keep in repair.

TABLE 8.—Average annual cost of repair per rod for several of the most commonly used fences.

Kind of fence.	Number of estimates.	Cost of repair per rod.	Kind of fence.	Number of estimates.	Cost of repair per rod.
Woven wire.....	787	\$0.024	Rail.....	89	\$0.045
Barbed wire.....	290	.025	Picket.....	17	.047
Board.....	26	.051	Hedge.....	1,067	.043

Detailed records covering the cost of repair of woven-wire fence along its right of way for a period of 4 years were furnished by one of the large eastern railroads. These figures, although slightly higher than those in the table, check very closely with them. The annual charge for the upkeep of hedge given in this table covers the cost of trimming the hedge. It has been found by averaging a large number of estimates that when hedge is trimmed once a year a man can trim 30 rods per day; when it is trimmed twice a year a man can trim 70 rods a day; and when it is trimmed three times a year a man can trim 110 rods a day. The cost of keeping the various kinds of wooden fences in repair is very high.

TABLE 9.—*Showing the width of the strip of land (from the center of the fence out on one side) which is made untillable by different types of fence.*

Kind of fence.	Number estimated.	Amount of land made untillable. ¹	Fence required to lose an acre of ground. ¹	Kind of fence.	Number estimated.	Amount of land made untillable. ¹	Fence required to lose an acre of ground. ¹
		<i>Feet.</i>	<i>Rods.</i>			<i>Feet.</i>	<i>Rods.</i>
Woven wire.....	4,048	3.29	802	Hedge (well trimmed).....	2,356	7.6	347
Barbed wire.....	3,853	3.42	772	Straight rail.....	2,066	3.57	739
Board.....	3,000	3.23	817	Worm rail.....	2,180	6.05	436
Picket.....	2,683	3.29	802				

¹ Should the fence run between two pasture fields, practically no land would be lost, but when it divides two cultivated fields the width of the strip of land made untillable, as shown by the table, should be doubled and the number of rods of fence required to occupy an acre of ground would be one-half that stated in the table.

When farm land is high priced the amount of land that is covered by fence rows becomes a matter of importance. For this reason worm-rail and hedge fences are not practicable throughout the corn belt, where there are still many of them in use. Table 9 shows the amount of land rendered untillable by different types of fence. They must be doubled if the fence divides two cultivated fields. When a forage or small-grain crop is grown less land is lost along the fence row than when corn, potatoes, or some other cultivated crop is grown, for much land is taken for turning along the fence row with the latter. Local practices also influence the amount of land along the fence row which is not cultivated. Thus, in certain parts of Iowa and adjacent States, it is not uncommon for a farmer to leave a headland 10 to 12 feet in width along his fences; these are used for driveways. In many localities of the East it is the practice to use one horse to plow along the fence row in order to get as close to it as possible.

It will be noted from the table that wire, board, and picket fences take up but a little over 3 feet on a side, while worm-rail fences occupy double this amount of land. The amount of land that the hedge fence renders useless for cultivation will depend upon the size of the hedge. If it is left untrimmed it will sap the fertility of the soil for more than a rod on each side of it; if it is kept well trimmed it occupies nearly double the amount of land taken by a wire fence. If the season is dry, a hedge does much more damage than when there is plenty of rainfall, as its root system extends out to a considerable distance and takes up moisture that is needed by the crops in the adjacent fields.

SUMMARY.

1. The large farm requires proportionately less fence than the small one, and the ratio of fence required to the acre decreases in proportion to the increase in size of farm up to a certain limit.

2. Stone, hedge, and the different types of wooden fences were desirable at the time they were first built, but changing economic conditions make them impracticable at the present time, and they are being replaced with wire fencing.

3. The best kind of wire fencing to erect depends on the purpose for which the fence is used. On a farm where mixed types of live stock are kept, a general-purpose woven-wire fabric is needed. If only cattle and horses are to be pastured, a coarser and less expensive

woven fence can be used. When fencing is needed to inclose extensive pastures where only cattle or horses are to be kept the excessive cost of a woven-wire fence would not make its use desirable, for losses to stock by injury on barbed wire would not be large enough to counterbalance the difference in the cost of maintaining the two different kinds of fences. This applies to the extensive farming areas of the West.

4. It is economy to use a heavy grade of woven-wire fabric. The cost of woven wire is based upon its weight, and a reduction in cost may be obtained by using a style of fencing that has the wires spaced only as close together as is needed to meet the requirements. It is false economy to reduce the first cost of the fence by using a light grade of wire.

5. To get the maximum of service out of a fence it is absolutely necessary that it should be well built. The corner posts must be placed solidly in the ground in such a manner that they can not be heaved by frost or drawn loose by the pull of the fence. The fabric should be strung tightly to the end posts, but it ought not to be tightly stapled to the line posts. It should be fastened to line posts in such manner that the wires may move in a horizontal direction to take care of the contraction and expansion due to changes in temperature, and to distribute the force of a blow along the fence line so that the strain will not come entirely on any one or two posts or any one point of the wire. A barbed wire should be placed a short distance above the top of the woven wire to prevent cattle and horses from crowding it down when reaching over or rubbing against the fence.

6. Cheaply constructed wire fences are expensive to keep in repair. Wooden and hedge fences require a large annual expenditure to keep them in shape.

7. Worm-rail and hedge fences occupy much more ground space than do the other types of fence in use in the area studied. Stone fences also occupy much ground, but very few of them were found in this area.

8. The cost of a good general-purpose farm fence constructed from durable materials will be as follows:

First cost:	Per rod.
Line posts; red cedar, hedge, locust, cement, or steel (1 rod apart) ..	\$0.28
Ends and braces; cedar, hedge, locust, cement, or steel (every 40 rods)	.125
Woven wire; 10 strands, 47 inches high, stays 12 inches apart, all No. 9	.40
Barbed wire; 1 strand placed 4 inches above top of the woven wire ..	.035
Staples	.005
Labor cost of construction	.09
Total	.935
Annual cost of upkeep:	
Repairs, including the cost of keeping the fence row clean	.024
Interest at 5 per cent on average investment (\$0.4675)	.023
Depreciation, estimating that the life of the fence is 22 years	.043
Total	.090
Interest on the land occupied at the rate of 5 per cent per year:	
108.6 square feet per rod, valued at \$125 per acre	.155
Total annual cost	.245

UNITED STATES DEPARTMENT OF AGRICULTURE



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WM. A. TAYLOR, Chief



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PROFESSIONAL PAPER.

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UTILIZATION OF AMERICAN FLAX STRAW IN THE PAPER AND FIBER-BOARD INDUSTRY.

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INTRODUCTION.

The purpose of this paper is to report recent tests on the utilization of American seed-flax straw in the paper and fiber-board industry. Successful commercial tests have been completed, wherein domestic flax straw and tow were used in place of imported flax waste in the manufacture of fiber counter boards, which are employed to a great and increasing extent in making toe boxes and counters for shoes. The boards made during these tests were pronounced satisfactory by manufacturers and were sold to the trade at the regular price for such boards.

From an economic point of view it seems inconsistent that this country should import flax waste from foreign countries for paper and board manufacture and at the same time actually burn one and one-half million tons of flax straw which is raised within its own borders. The reason usually given and naturally assumed is that it is more profitable to use the foreign article or that the domestic material is not suitable for the purpose. It will be shown in this report that these reasons have not been well founded.

¹ The work of investigating flax straw as a paper-making material was initiated by Mr. Charles J. Brand, now Chief of the Office of Markets and Rural Organization, when he was Physiologist in Charge of Paper-Plant Investigations of this bureau. Mr. Brand still retains supervision of this line of the bureau's activities.

NOTE.—This bulletin gives an account of recent work on the utilization of American seed-flax straw in the paper and fiber-board industry and will be of interest to chemists, flax farmers, counter-board manufacturers, and paper makers in general.

Among other reasons why flax straw should be investigated as to its paper value there should be cited the present condition and tendency of our rag paper-stock supply, which would welcome new sources of material at this time. About 70 per cent of the rags used in paper manufacture in the United States are imported from European countries. It is well known that very good writing papers have been produced from flax straw, but the cost of the processes employed up to the present time has not been justified by the quality and value of the product.

The rope-paper and high-grade sack-paper manufacturers also have been consuming an immense quantity of foreign raw material, in spite of the fact that it is known that American flax straw is capable of being used for some of these purposes. But here again the product has not justified the cost of the process. Manufacturers of cartridge or shot shell papers annually import approximately 2,000 tons of flax waste for the production of their paper, and the question of a satisfactory substitute is engaging their attention. From the paper maker's point of view, therefore, the flax crop represents a raw material of immense latent value, and, as will be shown, it is likewise a source of great latent value to the flax farmer.

Certain promoters have made attempts to exploit this material, but their efforts often have been based upon insufficient evidence and data. It is the object of this paper to show to what extent flax straw may be utilized in the paper-making and fiber-board industries and to suggest further possibilities.

One of our most highly prized and valued oils and one for which no satisfactory substitute has been found is linseed oil, which is manufactured solely from the seed of the common flax plant (*Linum usitatissimum*). The raising of flax is an industry of great importance, as is shown by the fact that the United States normally¹ has about 2,200,000 acres devoted to its culture, which produce about 20,000,000 bushels of seed, valued at approximately \$33,000,000. This seed flax of the Northwest is different in type from that cultivated primarily for fiber production, and because of this difference and the methods of cultivating and handling the crop the straw can not be made to produce a good spinning fiber.

The straw resulting from the harvesting and thrashing of this crop usually is burned, not because it has no intrinsic value, but because no adequate industrial use has been established to absorb it. With a production of three-fourths of a ton of straw per acre, the total annual tonnage of straw amounts to approximately 1,600,000 tons, of which not more than 200,000 tons are at present put to any profitable use.

¹ Five-year average, 1909 to 1913.

The utilization of the remaining 1,400,000 tons would be of immense economic importance, since (1) its paper-producing possibilities are equal to the annual production of wrapping paper and more than double the annual production of writing paper in the United States; (2) its sale would represent an added revenue to the farmers of about \$5,000,000 annually; (3) it would exert a very strong tendency toward maintaining the flax crop in our agricultural system; (4) it probably would result in the establishment of paper-manufacturing industries in sections where there are none; (5) it would aid in making our paper industry more independent of foreign raw paper-making materials; and (6) it would produce a keener realization of the latent value of some of our enormous crop wastes.

MIGRATION OF THE FLAX CROP.

The acreage of the flax crop has not remained permanent in any one section, and it is this constant migration which is of as vital importance as is its total available tonnage.

The total crop is variable in acreage and yield to the extent shown by Table I.

TABLE I.—*Acreage and yield of the flax crop in the United States for 1899, 1902, and from 1909 to 1914, inclusive.*

Year.	Acres.	Bushels of seed.	Year.	Acres.	Bushels of seed.
1899.....	2,110,000	19,979,000	1911.....	2,757,000	19,370,000
1902.....	3,740,000	29,285,000	1912.....	2,851,000	28,073,000
1909.....	2,083,000	19,512,000	1913.....	2,291,000	17,853,000
1910.....	2,467,000	12,718,000	1914.....	1,885,000	15,559,000

During its entire history flax has been a pioneer crop, being used as a first crop on the upturned virgin soil. This soil is claimed to be too rich for corn and other cereals, but, on account of the very meager root system of the flax plant, it thrives here at its best. Flax does not do as well on the same land until after other crops have been raised and the land put into grass again, when it is ready to be broken up for a new flax seed bed. The old prevalent idea that the flax crop is very exhausting to soil fertility has been shown to be a fallacy,¹ and it has been proved that it does not tax the soil fertility as much as either wheat or oats.

Table II gives statistics of flax acreage which show the migration of the crop in certain States since 1899.

¹ Bolley, H. L. Flax culture. N. Dak. Agr. Exp. Sta. Press Bull. 46, 4 p., 3 figs. 1911.

Bull, C. P. Flax growing. Minn. Farmers' Libr. Ext. Bul. 27, 8 p., illus. 1912.

TABLE II.—*Area devoted to flax in certain States in 1899, 1909, and 1913, showing the migration of the crop.*

State.	1899	1909	1913	State.	1899	1909	1913
	<i>Acres.</i>	<i>Acres.</i>	<i>Acres.</i>		<i>Acres.</i>	<i>Acres.</i>	<i>Acres.</i>
Ohio.....	3,092	552	.....	Iowa.....	126,453	15,549	28,000
Illinois.....	394	115	.....	Minnesota.....	566,800	358,426	350,000
Kansas.....	192,167	45,014	60,000	North Dakota.....	774,000	1,068,049	1,000,000
Nebraska.....	7,652	2,934	9,000	South Dakota.....	302,010	518,566	425,000
Michigan.....	883	261	.....	Montana.....	16	37,647	400,000
Wisconsin.....	11,263	9,423	9,000				

In 1879 Illinois, Iowa, and Indiana were the leading flax States. From present indications Montana is forging ahead very rapidly as a leading flax State, and Kansas and Nebraska also are becoming larger producers.

Since North Dakota is the largest flax State, the effect of migration in that State since 1902 has been determined. A north and south line of counties in the extreme eastern end of the State and a similar line of counties in the extreme western end have been chosen for comparison (Table III), to show the effect of migration.

TABLE III.—*Area devoted to flax in the eastern and western sections of North Dakota, in certain years, showing the westward migration of the crop.*

Year.	Number of acres in flax.		Percentage of total flax acreage of the State.	
	Eastern counties.	Western counties.	Eastern counties.	Western counties.
1902.....	892,000	145,400	47.0	7.6
1905.....	498,800	208,090	42.3	17.6
1910.....	267,000	404,200	23.6	35.7
1914.....	188,240	325,700	26.7	46.2

The figures in Table III show very clearly that the crop has migrated westward across the State and that in twelve years the eastern and western sections have changed places in relation to the total flax crop of the State. It naturally might be inferred that the crop will migrate eventually entirely out of the State, but, because of the short distance to the Rocky Mountain region and the Canadian line and because of increased knowledge of successful flax raising, it seems very probable that flax will continue to be an important crop in this State and region for a considerable period.

FLAX STRAW IN THE PAPER AND FIBER-BOARD INDUSTRY.

UTILIZATION OF FLAX STRAW IN THE PAPER INDUSTRY.

There is a great diversity of opinion as to the possibility of economically manufacturing paper from flax straw, but there is an almost unanimous agreement that it contains a certain proportion of

fiber which would be of value could it be separated economically from the straw. Different requirements are made of a raw material, however, depending on the grade of product desired. It might, for example, meet the requirements of the board manufacturer in regard to product and cost and not be capable of interesting the writing-paper or wrapping-paper manufacturer, for reasons of product or cost, or both. It may be found also that the straw can be used in only one or two grades of product, as is the case with poplar wood and esparto grass.

Much work has been done by different experimenters in testing this straw for its paper value, and samples of writing and sack papers have been produced which, so far as quality is concerned, seem to be satisfactory. A small flax-tow mill is in operation in North Dakota, which is equipped with a pulping boiler, beater, and other apparatus, and it has produced bleached flax pulp of an apparently satisfactory quality, from which good grades of writing paper have been manufactured. But the work, although promising, is yet in the experimental stage.

In 1908 the Bureau of Plant Industry, cooperating with the United States Forest Service, conducted a number of pulp-making tests with the straw and found that a very severe chemical action was required and that it was impossible to bleach the pulp economically with ordinary bleaching-powder solutions.

In spite of all the activity in this direction, however, no industry has been established whereby paper manufacturers have been enabled to utilize this immense and valuable crop waste.

UTILIZATION OF FLAX STRAW IN THE FIBER-BOARD INDUSTRY.

In the manufacture of certain grades of fiber board known as counter board, one of the main constituents is flax waste from the textile industries of Europe. The total quantity so used in this country is approximately 7,000 tons per annum. This waste is divided into four distinct classes, namely, flax card waste, flax card strippings, flax rove waste, and flax washed waste, depending on the particular operation from which each is derived. These wastes, with the exception of the washed waste, have a certain amount of flax wood shives associated with them, the card waste containing the most and the rove waste the least. The washed waste contains no shives and is the highest priced; likewise, the least used in board manufacture.

As to the possibility of substituting domestic flax straw for the imported flax waste, a comparison from a chemical and physical standpoint brings out the following facts:

(1) Flax waste is derived from retted flax straw and consequently contains very little of the mucilaginous pectin compounds, such as

are present in domestic unretted flax straw. For this reason alone flax straw would require the use of more chemicals in its reduction than does flax waste.

(2) The proportion of wood in flax straw is far higher than in flax waste, which probably would necessitate a higher consumption of chemicals in treating the former. If it should appear necessary to exclude wood shives from the finished product, it might be found necessary to reduce the wood to a greater extent than when using flax waste, in which case the reduction might require the employment of a higher steam pressure or a longer time of treatment, or both.

The greatest difference in a physical sense between straw and waste is that the former, being composed of lengths of the whole stalk, presents larger pieces, or masses, to the action of the chemicals, thus necessitating the employment of more time in the chemical reduction process. These chemical and physical differences, however, do not differ in kind but only in degree, from which it would be concluded that the method found to be satisfactory with straw would differ in no fundamental manner from that known to be satisfactory with waste.

LABORATORY EXPERIMENTAL TESTS ON THE PREPARATION OF PULP.

In March, 1914, preliminary work was started by the Department of Agriculture on the utilization of flax straw as a raw material for sack or wrapping paper manufacture. It was decided that, of all the fiber-treating processes, the milk-of-lime process was the most worthy of trial, after the following factors, among others, had been considered carefully:

Lower initial cost of factory installation.—On account of freight rates, which figure so prominently in the final costs of manufactured products, and because of the remoteness of the flax region from paper mills, it might appear advisable to establish pulp or paper mills nearer the source of raw-material supply. It would be inadvisable to install a process which demands a heavy expenditure per ton, such as the soda, sulphate, and sulphite processes, before the true value of the material were proved by actual manufacture for a reasonable period of time. Such a practical test might be prohibitive because of the shipping cost for such a distance, and few, if any, manufacturers could be expected to operate at a loss or even at a low profit for a sufficient period to determine the advisability of factory installation. The same remarks apply to the milk-of-lime process, but not to the same degree.

Tensile strength of the fibers preserved.—As is commonly known, caustic soda pulping lowers the tensile strength of fibers more than the milder milk-of-lime process.

Class of employees required.—The milk-of-lime process does not demand the employment of as large a staff or as great a variety of skilled help as the soda, sulphite, or sulphate processes.

The laboratory work consisted of pulping tests, beating and washing the pulp and making it into hand sheets. From the data gathered during this process and from the samples conclusions were drawn as to procedure and conditions to be employed on subsequent semi-commercial tests. It is fully realized that in general it is impossible to duplicate commercial working conditions on a small laboratory scale; therefore, laboratory results, valuable as they may be, should be interpreted commercially only with extreme caution. The following laboratory work and results are regarded, therefore, as approximate indications, to assist in subsequent semicommercial tests.

The flax straw used in these tests was of the ordinary seed-flax type raised in the vicinity of Fargo, N. Dak., was thrashed with the ordinary thrashing machine, as is the practice in that section, and was baled in an ordinary hay baler. The bales contained their proper complement of chaff, usually 30 per cent, and averaged 80 pounds in weight.

To serve as a fiber suitable for paper manufacture it is necessary to reduce the woody portion by cooking or bleaching to such a condition that the beater will be able to disintegrate mechanically or separate the woody shives to such a size or condition that they may be removed from the true fiber by washing in the regular manner. The proportion of woody matter that it is necessary to remove depends naturally on the grade of product desired.

Pulping tests, technically known as "bleaches," were conducted in an iron rotary boiler of 10 gallons capacity, heated by means of direct steam and gas burners, and rotating 1 revolution per minute.

In conducting a bleach, the boiler is charged full of straw, from which a sample has been drawn for a moisture determination, in order to calculate the weight of bone-dry straw employed. The predetermined quantity of lime (burned lime), calculated in percentage of the bone-dry straw, is added in the form of milk of lime, together with sufficient water to amount to 1 gallon per $2\frac{1}{2}$ pounds of straw. After closing the boiler and rotating a few times, direct steam at 110 pounds pressure is admitted, the gas burners underneath are lighted in order to counteract excessive radiation, and the charge is heated to a certain point in one hour.

The control of the degree of heat in a boiler is accomplished in practice by a steam-pressure gauge which bears a direct relation to the temperature of the charge, but since it is not pressure but temperature which induces the chemical actions, it would obviously be as correct to employ temperature as pressure for a guide. In all of the laboratory work the temperature control was used, being effected by a thermometer inserted in a horizontal well extending from the end of the boiler to the center of the charge. After the desired tem-

perature has been reached this degree is maintained constantly for the required number of hours, after which the burners are removed and the boiler cooled in about half an hour by means of a small stream of water applied to the boiler shell. The resulting stock, on removal from the boiler and after remaining unwashed over night, is well washed with water, pressed into a uniform cake, weighed, and a sample drawn for a moisture determination, from which data the yield of total stock is determined.

The stock after bleaching shows the bark more or less completely resolved and the bast very loosely held in the structure. The inside woody portion appears practically unchanged, but in reality it has

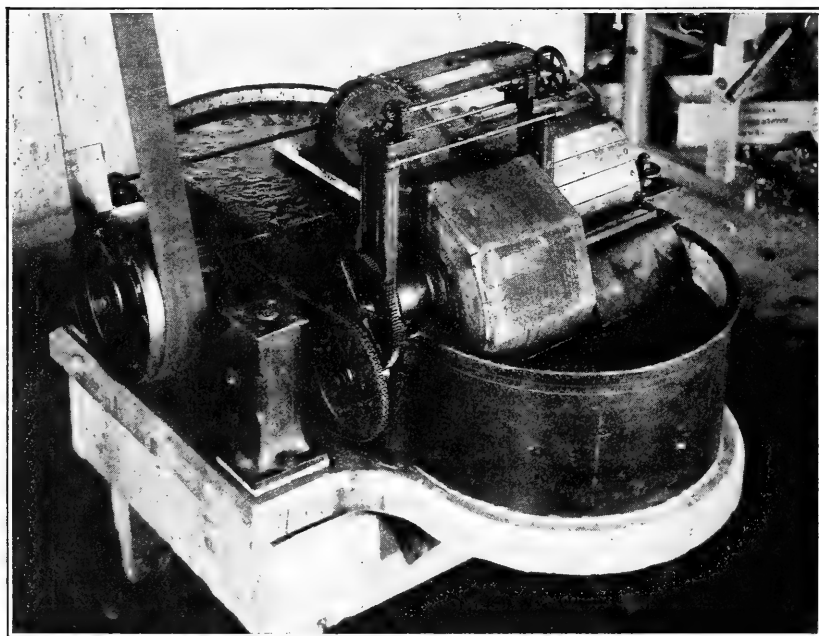


FIG. 1.—Experimental 10-pound beater, supplied with washer.

suffered a chemical and physical change whereby the structure is mechanically weakened.

Next, the stock is "beaten" in an experimental 10-pound beater (fig. 1), which consists of a trough in which the stock is caused to circulate and pass between a bedplate of coarse knives or bars and a series of similar knives set in the periphery of an iron roll making about 150 revolutions per minute. The distance between the two sets of knives can be regulated and altered to any degree, according to the effect desired. This action causes the bleached stock gradually to be distintegrated into its ultimate cells, the bark being reduced to bast cells and the small connecting cells of the structure and the

woody portion partly to very fine shives and partly to the ultimate wood cells.

The measurements shown in Table IV give an idea of the kinds and relative sizes of the various cellular elements of which flax pulp is composed. The pulp in this case was obtained by the soda process, on account of the more complete separation of the cells in the pulp (fig. 2).

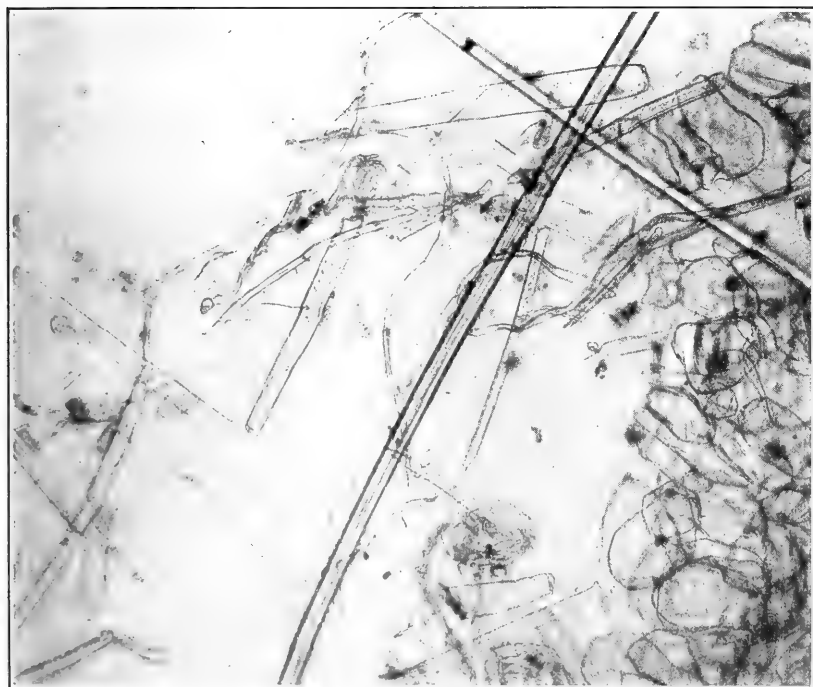


FIG. 2.—Microphotograph of pulp from flax straw before the smaller cells are removed.
(Magnified 103 diameters.)

TABLE IV.—*Dimensions of the cells of flax pulp.*

Kind of cells.	Dimensions (millimeters).						Ratio of length to width.
	Length.			Width.			
	Maximum.	Minimum.	Average.	Maximum.	Minimum.	Average.	
Pith cells (from the central portion of the stalk).....	0.14	0.08	0.10	0.08	0.06	0.06	1.5
Epidermal cells.....	.11	.07	.08	.03	.01	.02	4.3
Short parenchyma cells.....	.13	.09	.11	.02	.01	.02	7.2
Long parenchyma cells.....	.40	.18	.29	.04	.02	.03	9.2
Spiral, pitted, and other vessels.....	(1)	(1)	(1)	.02	.009	.011	.....
Wood fibers (from the woody portion of the stalk).....	.425	.16	.20	.013	.009	.011	17.5
East fibers (the long fiber of the plant, which is of value to the paper maker).....	64	5	.....	.039	.010	.019	.....

¹ Extending throughout length of plant.

The short fibers or cells are not sufficiently long or correctly proportioned and shaped to possess the felting quality on which their value largely depends in paper manufacture; moreover, in distinction from the long bast fiber, they are liquefied, which renders them very undesirable in the manufacture of durable products.

The separation of the dirt and short fibers from the long true fibers was accomplished in the laboratory, as in practice, by means of a washer, which is a rotating drum covered with 20-mesh wire cloth on the sides and having helical scoops inside connecting with a hollow trunnion. This washer is attached invariably to the beater and by being lowered about one-third its breadth into the circulating stock it removes water, dirt, and short fiber, while fresh water is admitted at the other end of the beater.

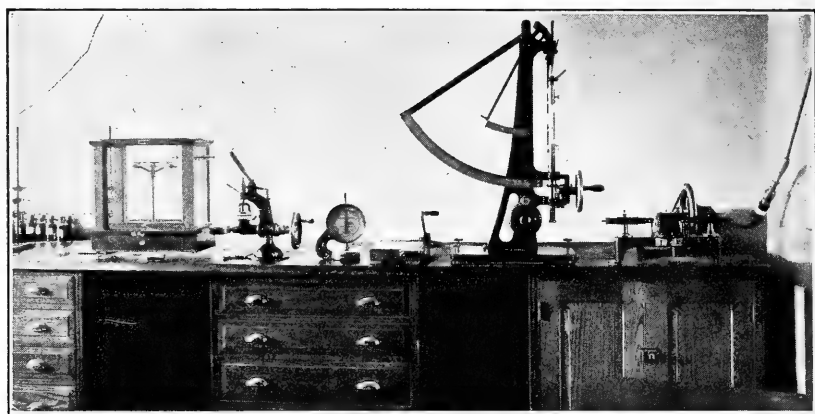


FIG. 3.—Paper-testing machines in a constant-humidity room.

Obviously, this light beating and washing should be carried to different degrees, depending on the quality of the product desired. For example, a medium grade of fiber board would not require as much washing as one of higher grade and a stock suitable for wrapping or sack paper would require a very complete washing.

After having been washed to the desired degree, the stock is drained from the beater, pressed, weighed, and sampled for a moisture determination, in order to calculate the yield of the washed fiber. It is then returned to the beater, and the long true fiber is reduced to a degree which is suitable for manufacture into a sheet of paper.

All sheets were made waterleaf on a hand mold $5\frac{1}{2}$ by 10 inches, dried on a steam-heated cylinder at 105° C. under a definite tension, and subsequently given physical tests under constant conditions of temperature and relative humidity.

To show the effect on the physical constants of a paper caused by drying the wet handmade sheet under different tensions, the re-

sults of one series of tests on a lime-cooked flax-straw paper are here given (Table V). The wet sheets were placed on a cloth-covered iron cylinder heated by steam to 103° C. and held down by placing on top a cloth which was maintained at a definite tension. The sheets shrank more and cockled more under a light tension than under an increased tension. The physical tests were made at 80° C. and 65 per cent relative humidity (fig. 3).

TABLE V.—*Effect on the physical constants of paper dried under different tensions.*

Tension of cloth.	Breaking length of sheet (meters).	Folding factor of sheet, ream 25 by 40 by 500.
550 grams.....	3,165	0.00312
1,245 grams.....	3,420	.00407
2,155 grams.....	3,810	.00487
3,240 grams.....	4,150	.00571
3,700 grams.....	3,960	.00405

From Table V it appears that within certain limits the strength and folding quality of a sheet depend to a considerable degree upon the method of drying.

Bleaches were made with from 12 to 25 per cent of burned lime, calculated on the bone-dry weight of the straw used, employing temperatures from 135° to 170° C. and treating at the definite temperature from 6 to 10 hours.

The most thorough reduction and generally satisfactory results were obtained with 14 per cent of lime acting for 10 hours at 170° C., or the equivalent of 100 pounds steam pressure. The yield of total fiber obtained did not vary much with the different bleaching conditions, ranging from 60 to 68 per cent of the bone-dry weight of the original straw employed. Determinations of the yield of washed or separated fiber on the satisfactory bleaches gave an average of 32 per cent of the bone-dry weight of straw employed.

MILL TESTS ON THE MANUFACTURE OF WRAPPING PAPER.

Tests of wrapping paper from flax straw were made at Cumberland Mills, Me. Semicommercial machines were used, and most of the work was performed by the regular mill employees.

The straw used in these tests was raised in the vicinity of Fargo, N. Dak., being the same as that used in the laboratory tests. It was first sieved on a 4½-mesh screen, in order to remove the loose chaff composed of dirt, seeds, and empty seed capsules, which amounted in total to 24.5 per cent of the original straw.

Chemical reduction was effected in a steel, rotary pulp boiler, 6 feet long by 4 feet in diameter, which was supplied with a thermometer well, pressure gauge, and pipes for relief and direct steam inflow.

Bleach No. 193.—A charge of 277 pounds (242 pounds, bone-dry weight) was treated with 15 per cent of burned lime (36.4 pounds) and 100 gallons of water, the lime being slaked in part of the water before being added. Direct steam was admitted, so as to bring the charge up to 148° C., or 50 pounds steam pressure, in 1 hour; then regulated so as to maintain this pressure for 10 hours, after which the pressure was relieved and the contents removed. This stock was followed down with a fairly light roll and washed for 3 hours in a 400-pound beater, at which point the stock was removed, drained, pressed, weighed, and sampled for moisture content. From these data the yield was found to be 64.6 per cent of the sieved straw, or 48.7 per cent of the original bone-dry straw.

Bleach No. 194.—This bleach was made in the same manner as No. 193 and beaten and washed 3 hours, after which the stock from No. 193 was added to it in the beater. The combined stocks were beaten a total of 19 hours, the last 7 of which were fairly hard, the washer being used the first 4 hours. The long bast fibers were very strong and not easily reduced; likewise, the woody portion did not completely reduce to the separated individual fibers, but remained as more or less fine shives, or cell aggregates. The washer used in this work was 60-mesh, while a much coarser, possibly 20 or 25 mesh, would have removed many more of the shives and given a far better product. This unsized and unscreened stock was pumped to the stuff chest and run over a 30-inch Fourdrinier paper machine, in conjunction with a Jordan type of refiner. The stock acted well on the machine wire, was strong after the second press rolls, did not cockle on the driers, but became very brittle on drying, doubtless due to the large amount of woody shives present. It was apparent that more wood must be removed from the finished product. This could be accomplished by removing it from the straw before treatment, or by more severe chemical treatment, or by a harder beating and washing. Another test was made on the same lot of straw, which gave a sieving loss of 35 per cent of the original straw.

Other bleaches.—Three bleaches, Nos. 202, 203, and 204, were made, similar to bleach No. 193, using 14.7 per cent of lime and treating 10 hours at 160° C., equivalent to 60 pounds steam pressure.

The stock from bleach No. 202 was beaten and washed eight hours in a 400-pound beater, following the roll down fairly hard. At this point the stock was removed and weighed, giving a yield of 63.8 per cent of the sieved straw, or 41.5 per cent of the original bone-dry straw.

Stock from bleaches Nos. 203 and 204 was beaten and washed 7½ hours, after which the washed stock from bleach No. 202 was added and the whole beaten and washed for 18 hours. The feeling and appearance of the stock improved during the whole beating and washing period, but it was still apparent that not enough wood was being removed. Competent employees judged that there were 250 to 300 pounds of stock in the beater at this point, which would represent a yield of 40 to 47 per cent of the sieved straw, or 26 to 30.5 per cent of the original dry weight of straw.

The stock was sized with 1 per cent of size and 3 per cent of alum and run over the Fourdrinier paper machine at a speed of 91 feet per minute. The stock acted very well on the machine, but, as in the previous test, the sheet became brittle on drying. It was evident that a still harder or different bleach was necessary or that the manner of beating and washing should have been different.

MILL TESTS ON THE MANUFACTURE OF FIBER BOARD.

When the experimental work on the utilization of flax straw in the manufacture of paper had reached this point, there was a great uneasiness in the fiber-board industry concerning the supply of foreign raw material because of the outbreak of the European war. As previously noted, there are imported into the United States annually about 7,000 tons of flax waste derived from the foreign textile industries, which are used almost exclusively in the manufacture of the counter-board grade of fiber boards. These counter boards are used chiefly for the manufacture of counters and toes for the stiffening of the heels and toes of shoes.

The price of this flax waste has ranged from \$25 to \$29 per ton from 1908 to 1912, inclusive, and the average price in 1913 was \$36.50. The waste had been constantly deteriorating in quality, until the same grade was 20 to 25 per cent poorer for fiber-board manufacture than in 1908-9. Soon after war was declared the available supply of flax waste was bought up and stored for future manufacture, and the importations were greatly curtailed. Finally, the waste was withdrawn from quotation, after reaching prices of about \$65 per ton.

It was thought that if American flax straw could be substituted for the imported waste, this would be the most propitious time to induce manufacturers to cooperate in the work and establish a market for this crop waste. One of the leading counter-board factories signified its willingness to cooperate in the project and kindly placed at the disposal of the Bureau of Plant Industry many of its regular machines and its semicommercial testing equipment.

The semicommercial testing equipment consisted of a direct steam, iron, rotary bleach boiler, about 2 feet in diameter by 5 feet in length;

a 10-pound washing and beating engine; and a wet machine capable of producing board sheets 15 by 22 inches.

After several preliminary tests on the small machines it was found that flax straw bleached with 14 per cent of lime for 15 hours at 170° C. and washed and beaten in the regular manner made a board which was almost invariably too hard and brittle, but if used with an equal amount of bleached old mixed string and an equal amount of bleached board cuttings a satisfactory board could be made. Still there was usually a little too much brittleness.

Test No. 115.—A test was then made, designated as No. 115, using the large beater and wet machine. Two charges of 255 pounds each were made in a rotary pulp boiler, bleaching with 14 per cent of burned lime at 170° C. for 15 hours. About 275 pounds, dry weight,



FIG. 4.—Fiber-board press or calender.

of this stock was charged into a 700-pound beater and washed and beaten with a hard brush for 2½ hours, after which the roll was raised and the washing continued one hour longer. The wood was reduced and removed to a considerable extent, and, although the bast fiber was reduced in length somewhat, there was no bast-fiber loss in the wash water. At this point the workmen pronounced the stock very similar in appearance and action to that from flax waste.

The washed flax was then added to a beater containing an equal weight of bleached mixed strings, which had been washed and beaten for seven hours, and an equal weight of bleached board cuttings was added. The furnish therefore was one-third mixed strings, one-third flax straw, and one-third board cuttings. This charge was beaten down, sized, and loaded by the experienced beatermen of the company in the equivalent of 12 hours total time. The stock was run into board on a regular 44-inch wet machine and dried in the loft

for 15 hours, after which it was put through the board calender (fig. 4).

The thin or light-weight sheets were too soft, those of medium weight satisfactory, and the heavy ones a little too brittle. It should be stated that the stock needs to be reduced to different fiber lengths, depending on the weight of board desired. Those boards of this test which were of medium weight and were satisfactory were sold with the company's regular stock and no complaint was received from them.

Test No. 118.—A test was then made, using the large beater and regular wet machine, employing the same furnish as in test No. 115, but the charge of mixed strings was added unwashed to the charge of flax straw, which had been washed for 3 hours. This combined charge was washed for $1\frac{1}{2}$ hours more, when the furnish of board cuttings was added and the charge sized, loaded, and beaten off in a total of 14 hours, or 11 hours after the addition of the strings. The board was tough, but much too soft. The old saying that "the paper is made in the beater" seems to apply equally well to fiber-board manufacturing, as the furnish in this test was the same as in test No. 115 and the difference in the method of furnishing was insufficient to account for the difference in the two products.

Test No. 125.—A test on the large mill machines was now made, including the bleaching in the company's large bleach boiler. Three thousand pounds of the baled straw were pitched over carefully with fine pitchforks and freed from chaff, which amounted to 33 per cent of the original straw. The 2,000 pounds of sieved straw were charged into the boiler, together with 14 per cent of burned lime and 800 gallons of water. The charge was heated by direct steam to 105 pounds pressure in $1\frac{1}{2}$ hours and maintained at this pressure for 15 hours, after which the pressure was relieved in $1\frac{1}{2}$ hours and the charge removed. For some reason the stock did not appear quite as well reduced as was the bleach carried out under the same conditions in the smaller boiler at Cumberland Mills, Me.

A 500-pound beater furnish of one-third domestic flax straw, one-third mixed strings, and one-third board cuttings and sulphite screenings was washed and beaten in the following manner: The flax-straw stock was first washed in the beater for 5 hours, when the mixed-string stock was added, after having been washed for $1\frac{1}{2}$ hours. The charge was beaten 4 hours, when the one-third of board cuttings and sulphite screenings was added and the whole beaten 6 hours more. The furnish was sized and loaded in the regular manner. This stock was run over a 44-inch wet machine, loft dried, and calendered, giving a board which, although not perfectly satisfactory, was readily used in the trade.

It was realized at this point by the officials of the Department of Agriculture and the fiber-board manufacturing company that the

flax straw contained a fiber which was very promising for this line of product, but the woody portion was so high that it offset to a large degree the desirable quality of the bast fiber.

FLAX TOW IN THE FIBER-BOARD INDUSTRY.

CONDITION OF THE FLAX-TOW SUPPLY.

Field work in Minnesota and North Dakota, which was undertaken after these tests were made, developed many factors of direct and immediate value to this project and to the paper and fiber-board industry in general.

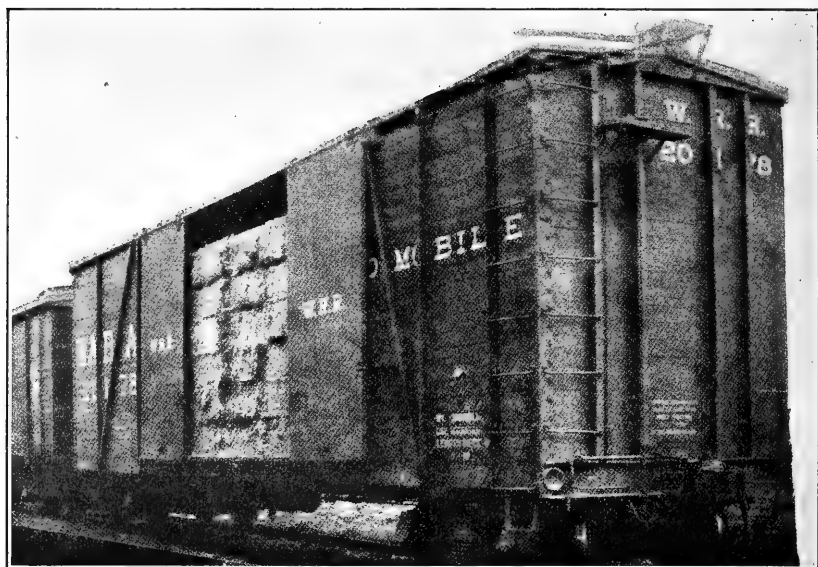


FIG. 5.—A carload of flax upholstery-tow bales.

Of the total quantity of unused flax straw resulting from the thrashing of the flax crop, fully 90 per cent is actually burned in the fields. Farmers located near tow mills are able to sell all of their straw, getting in some sections \$2.50 to \$3.50 per ton, loose, hauled to the mill. In one section farmers were selling at \$1 per ton in the stack. In those sections where flax is raised more abundantly, such as central and western North Dakota, it is the general belief that the baled straw can be delivered f. o. b. cars in large quantity at not more than \$4 per ton. (Figs. 5 and 6.)

About the only profitable use to which the straw is put is in the manufacture of flax tow, which is consumed for the most part in upholstery and as a packing material for crockery, glassware, etc. This tow is made from tangled and broken flax straw after it has

been thrashed in ordinary grain-thrashing machines, without retting, and is very different in character from the flax tow of the spinning mills. A comparatively small quantity is manufactured into insulating boards, such as are used in building construction and refrigerator cars; also a very small amount is used in the manufacture of rough twine. There are about 10 flax-tow mills in the flax region, the largest of which consumes over 30,000 tons per year, while some use not more than 1,000 tons.

The flax-tow machines consist essentially of a series of corrugated rollers operating in pairs under considerable pressure, through which a uniform layer of straw is rolled. The woody portion is crushed and broken into small pieces, which fall away between the rolls and are further removed by dusting and screening devices.

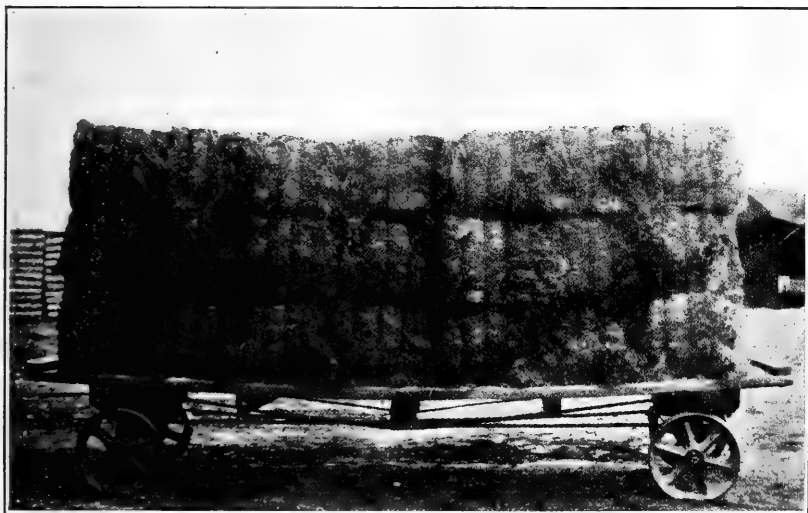


FIG. 6.—A truck load of flax upholstery tow bales.

Flax upholstery tow is sold under four grades and normally in carload lots at the following prices: Coarse, \$16; medium, \$18; fine, \$24; extra fine, \$32. These prices were the quotations in September, 1914, for baled flax tow, f. o. b. St. Paul, Minn., at which point flax straw can be bought at \$7 per ton, baled, in carload lots. The different grades vary in the amount of woody matter removed and the degree of softness of the tow (fig. 7).

Considering these prices of tow, the amount of wood removed, and the general physical condition of the material, it would seem that tow would be a more desirable as well as a more profitable raw material than straw for the fiber-board manufacturer, if not indeed for the paper manufacturer. In the case of medium tow, for example, 2 tons of straw are required to make 1 ton of tow, which is a consider-

able item where the material must be shipped east to the board and paper mills, as most of the counter-board mills are in or near New England. It is also a considerable item when it is recalled that the board and paper manufacturer must remove more or less (and in some cases practically all) of the wood during the manufacturing process before a pulp is obtained suitable for his purpose. Moreover, the physical condition of the material is such that it is more amenable to chemical pulping processes, yielding to less expensive processes and producing a more uniform and satisfactory product.

MILL TESTS ON THE MANUFACTURE OF MEDIUM FLAX TOW.

On account of previous and satisfactory laboratory results on flax tow and because of the satisfactory condition of the tow industry near the flax region, it was decided to be advisable in continuing board tests to employ flax tow instead of flax straw, as had been done up to this time. With this in view, a cooperative test was made in

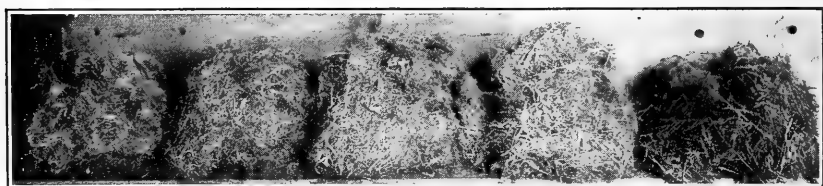


FIG. 7.—Small samples of flax straw and tow. From right to left: Straw, coarse tow, medium tow, fine tow, and extra fine tow.

a large tow mill at St. Paul, Minn., in which 24.8 tons of straw were manufactured into 14.7 tons of medium tow, or 59.3 per cent of the original straw, which yield is believed to be somewhat higher than that obtained in ordinary practice. The bales average 100 pounds, and 15 tons can be loaded into a car. This lot of tow was shipped to a counter-board mill in Maine, where cooperative board tests were made later, while four bales were sent to the Washington laboratory for preliminary tests as to the most suitable method of treatment. From observations made during this tow test, it was evident that by very slight modifications of the tow machinery considerably more woody matter could be removed, greatly to the advantage of the paper manufacturer.

LABORATORY TESTS ON THE TREATMENT OF MEDIUM FLAX TOW.

The tow used in these tests was that manufactured at St. Paul, as previously described. In order to obtain an idea of the amount of loose woody matter still remaining in the tow, a weighed quantity was shaken out lightly by hand, yielding 16 per cent of woody shives. These shives are of no value to the paper or board manufacturer, and

it is believed that they can be removed readily at the tow mills at a very slight increase in the cost of processing the tow.

A series of lime cooks or bleaches was made in the laboratory, employing a 38-liter rotary pulp boiler operated by direct steam, from the results of which it was concluded that a treatment with 14 per cent of burned lime for 4 hours at a steam pressure of 100 pounds per square inch would give a product satisfactory for fiber-board manufacture. Under this treatment, the yield of washed or separated fiber was 48 per cent of the bone-dry weight of tow used.

Table VI gives a partial list of the laboratory bleaches, illustrating the method of determining the correct amount of lime necessary to be used.

TABLE VI.—*List of bleaches, showing the method of determining the correct amount of lime to be used.*

Cook No.	Lime used.	Time of treatment.	Pressure per square inch.	Waste liquor (per liter).	
				Acidity.	Soluble lime salts.
	<i>Per cent.</i>	<i>Hours.</i>	<i>Pounds.</i>	<i>Grams, acetic acid.</i>	<i>Grams, CaO.</i>
246.....	12	5	100	0.97	6.8
247.....	14	5	100	.26	5.8
248.....	15	5	100	<i>Per cent, CaO.</i> 0.008	6.3
249.....	17	5	100	.023	6.9
250.....	17	5	100	.024	7.2

The yield on cook No. 250 was 73.8 per cent of total fiber and 48.6 per cent of washed or separated fiber. Washing was done in the beater by means of a regular washer covered with 30-mesh wire cloth, such as is used in fiber-board mills.

A series of bleaches on flax straw is recorded in Table VII, showing the extent to which fiber can be injured by not employing sufficient lime in the bleach.

TABLE VII.—*List of bleaches, showing the extent of injury to fiber through insufficient lime.*

Cook No.	Lime used.	Time of treatment.	Pressure per square inch.	Waste liquor (per liter).		Tensile strength of ultimate fiber per square mm. of solid cross section. ¹
				Acidity.	Soluble lime salts.	
	<i>Per cent.</i>	<i>Hours.</i>	<i>Pounds.</i>	<i>Grams, acetic acid.</i>	<i>Grams, CaO.</i>	<i>Grams.</i>
243.....	12	6	100	2.11	7.4	.....
244.....	14	6	100	.97	9.1	57,000
245.....	16	6	100	(2)	7.0	65,000
251.....	18	6	100	<i>Per cent, CaO.</i> 0.006	7.0	.....
252.....	18	6	100	.03	7.5	85,000

¹ Determined by a method devised by this laboratory.

² Barely alkaline.

Fiber-board manufacturers would do well to pay more attention to the reaction of their waste liquors. A few drops of 1 per cent phenolphthalein in 50 per cent alcohol dropped into about a quarter of an ounce of the waste liquor should produce an intense red color at once.

MILL TESTS ON THE MANUFACTURE OF FIBER BOARD.

Fiber-board mill tests were again undertaken in a fiber-board mill in Maine, but flax tow was used instead of the straw that was employed in the previous work. The regular machines were used in all of these tests and the work was performed by the regular mill employees; in other words, the flax tow was subjected to actual commercial manufacturing conditions, although in some of the tests slight changes in procedure were made, as will be shown.

Bleach No. 234.—A charge of 4,062 pounds was treated with 14.6 per cent of burned lime by slaking 578 pounds of the lime in 1,600 gallons of water in the bleach boiler, then adding the charge of tow. Direct steam was admitted, and the pressure was brought up to 110 pounds in 3 hours and maintained for 4 hours, after which the pressure was relieved in 2 hours and the charge dumped.

After remaining on the drain floor over night this stock was made into a 500-pound beater furnish of one-third flax tow, one-third mixed strings, and one-third board cuttings, in the following manner: The mixture of tow and mixed string was washed in the beater for 2 hours, when the board cuttings and sulphite screenings were added and the charge beaten off in a total of 12 hours. Near the end of the beating, the filler, color, and size were added. This stock was run over a 44-inch wet machine, loft dried, and put through the board calenders. The wet boards from the wet machines measured 38 by 44 inches, and after they were dried and calendered they measured 33 by 44 inches, which is about the correct amount of shrinkage. These boards were sold in the trade, but not as counter boards, as they were too brittle for that grade. The brittleness was due, according to the management and employees, to the fact that the stock was beaten too short. In working with any new material, its characteristics and differences must be learned before its full possibilities can be developed, and many failures must be expected during the earlier stages of development.

Bleach No. 235.—This bleach was made in the same manner as No. 234, but 15 per cent of lime was used and the charge cooked at a steam pressure of 75 pounds for 9 hours, the total time of cooking being 12 hours. The stock from this bleach was used in the same furnish and manner as that of bleach No. 234. This furnish was beaten off in a total of 12 hours, loaded, colored, and sized, as in the previous test. The stock showed up very well in going over the wet machine, giving a board measuring 38 by 44 inches wet, which after loft drying and calendering measured 33 by 44 inches. This

board was pronounced by the fiber-board employees and the management officials to be equal to those boards of this class in which imported flax waste is used, and it was sold on the market by the cooperating mill as a second-grade counter board at the regular price of such boards, namely, 5 to 5½ cents per pound (fig. 8).

The thin boards of this run were somewhat soft and the thick boards were somewhat brittle, which naturally would be the case, since each thickness of board requires that the stock be beaten accordingly.

Additional tests.—Three other complete tests were made like the two above recorded, and although the results were not as satisfactory as those of No. 235, the board was sold as second-grade counter board and no complaint has been received from it.

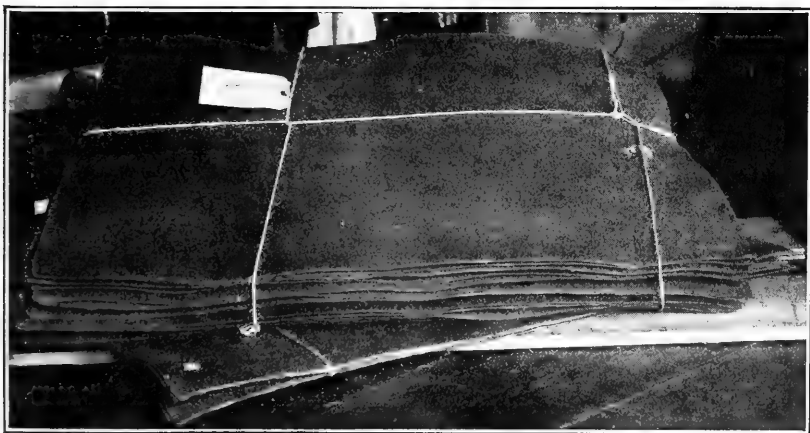


FIG. 8.—A package of counter boards, in the manufacture of which domestic flax upholstery tow was employed in place of imported flax waste. Size of boards, 33 by 44 inches.

Unfortunately, no methods of testing boards have been devised which give the results as a numerical expression, the usual method being to bend and fold the board with the fingers in different manners, according to the use to which the board is to be employed, and noting the degree with which it breaks or cracks.

YIELD OF PRODUCT AND COMPARATIVE COSTS.

It is impossible in the mill tests to determine the yield of washed or available fiber derived from the straw and tow, even as compared with imported flax waste. The general opinion of the management and employees who followed the tests was that there was no appreciable difference in yield so far as could be determined by observation during the tests.

Laboratory determinations of the yield of washed fiber on 6-pound samples of flax straw, medium flax tow, and the best grade of imported flax waste gave the results shown in Table VIII.

TABLE VIII.—*Yield of washed fiber from flax straw, medium tow, and imported flax waste.*

Material tested.	Lime used.	Time of treatment.	Pressure per square inch.	Yield of washed fiber.
	<i>Per cent.</i>	<i>Hours.</i>	<i>Pounds.</i>	<i>Per cent.</i>
Flax straw.....	18	6	100	41.2
Medium flax tow.....	17	5	100	50.4
Imported flax waste.....	10	10	45	55.7

It should be remembered that these are experimental results, and although necessarily they do not represent the mill yields, they are strictly comparative. Probably the yields are lower than those in mill practice. Although domestic flax tow yields a lower percentage of washed fiber than does imported flax waste, the lower price paid for the former makes the total cost of the washed product made from domestic tow delivered as far east as Boston very little more than the total cost of washed fiber produced from imported waste. It would thus appear that, so far as both cost and quality of product are concerned, the domestic flax tow from the region of the Dakotas can compete against imported flax waste in the manufacture of counter boards even if the manufacture is conducted as far east as Boston. If the board manufacture is conducted near the flax region, the results would be about as 7 to 5 in favor of domestic tow.

SUGGESTIONS FOR FLAX FARMERS.

Many letters have been received from the farmers of the flax region asking for information in regard to the profitable disposal or utilization of their waste flax straw.

So far as its use in the paper industry is concerned, it is obvious that no immediate benefit can be derived until its value in this line is proved and industries are established which will create a market for it. The success of the project depends to a certain extent upon the farmer. The price of his straw must net him a fair profit, but at the same time this price must be such that the material will be attractive to the paper manufacturer. When the time comes that the paper industry will be in a position to use this material the flax farmer should have made arrangements to supply the material in such a manner that he may secure his proper proportion of the benefits and profits.

It would seem, from the paper-maker's as well as the farmer's standpoint, that the most beneficial and profitable as well as generally satisfactory method of assembling this material for the market would be to establish a number of small tow mills throughout the region where the most flax is grown rather than to establish a smaller number of larger tow mills. This method would render more material available, benefit more farmers, and place the product on the market at a lower price.

As a suggestion for consideration, farmers may find it advisable to act cooperatively. For example, the farmers within a 5-mile radius might own and operate a tow mill of sufficient capacity to market the entire quantity of straw within their area. Under this system the farmer not only would benefit by the sale of his straw but would receive also a profit from the manufacture of the tow.

From present indications it appears that different grades of tow should be produced for the paper industry, depending on the grade of paper to be manufactured. For example, a medium grade of tow might answer the requirements of the board manufacturer, while a fine or extra fine grade would be required by the wrapping-paper manufacturer. Investigation doubtless will be continued along the wrapping-paper and writing-paper lines, in order to develop a market which will absorb an appreciable amount of this large and potentially valuable crop waste.

CONCLUSIONS.

Should flax straw or tow prove to be of value to the paper or board industry, the condition of the raw-material market at the present time is such that the new supply would be very welcome to the trade. Since this work was undertaken, many calls for information have been received from the mills and many offers of cooperative help have been extended, which show conclusively the attitude and needs of the industry.

If, as seems very probable, domestic flax straw or tow can replace imported flax waste in the manufacture of counter boards, it should open up a market for about 20,000 tons of straw, which, although a small amount, is a step in the direction of the advancement of home industry.

Should the straw be able to compete successfully in the manufacture of writing papers it should open up a market of between 200,000 and 400,000 tons of straw per annum, the sale of which would represent an added revenue to the flax region of \$800,000 to \$1,600,000. This country is importing over \$2,000,000 worth of rags per annum, which are used largely in the manufacture of writing papers.

The wrapping and bag paper lines offer like possibilities, which are worth consideration in this general project.

The flax crop, which furnishes normally \$33,000,000 worth of flax seed, yields about 1,400,000 tons of straw, which is put to no profitable use and for the most part is burned in the fields. It is purely a waste product and, moreover, one which is already assembled to a large degree. It has always been a migratory crop, but increased knowledge of its nature and proper methods of raising are beginning to check this condition. Moreover, if the flax farmer who realizes \$12 per acre for his seed can deliver his straw at tow mills or other central points for, say, \$4 per ton, he is realizing an increased revenue

per acre of 25 per cent, which fact also will exert a restraining tendency on the migration of the crop.

Of this large crop waste, 91 per cent is raised in the following States: North Dakota, 43.7 per cent; Minnesota, 16.1 per cent; South Dakota, 15.7 per cent; and Montana, 15.3 per cent. From the total of 1,600,000 tons of flax straw not over 200,000 tons are put to a profitable use in the manufacture of flax tow and insulating material. Many fruitless attempts to utilize this straw in paper manufacture have been made, but thus far no permanent industries have resulted.

In the manufacture of fiber counter boards used in shoe manufacture, there are used annually about 7,000 tons of flax waste imported from Europe. Since the outbreak of the European war the importation of this material has been curtailed and its price has advanced 100 per cent. For these reasons, among others, the Department of Agriculture has investigated the adaptability of domestic flax for supplying this market. As the result of laboratory and commercial cooperative tests in a counter-board mill, counter boards were produced, employing domestic flax tow in place of imported flax waste, which were pronounced satisfactory and were actually sold by the mill to the trade for counter manufacture at the regular price of counter boards, namely, 5 to 5½ cents per pound.

Flax tow manufactured in the flax region can compete more successfully than can flax straw with imported flax waste, and, as all counter board is of eastern manufacture, it would seem logical to consider its manufacture near the source of flax-straw supply and near the large and increasing Middle West market. The farmer in the flax regions would then be situated most favorably for the marketing of his flax straw.

It is realized that this source of utilization would open a market for not over 20,000 tons of straw annually. It is proposed, therefore, to extend this investigation into the lines of wrapping and writing paper manufacture. If successful methods of so using flax straw and tow are discovered, a large proportion of this great and potentially valuable crop waste could be utilized. This not only would benefit the farmer but would exert a very strong tendency toward maintaining the flax crop in our system of agriculture.

The attention of the Department of Agriculture has been called repeatedly to various schemes which have been promoted by individuals and organizations in attempts to lead the farmer to believe that there are demands for flax straw greater than careful investigation has shown to exist. The farmer is advised, therefore, to investigate carefully any schemes which have not been thoroughly tested and found to be of practical value by reputable manufacturers.

UNITED STATES DEPARTMENT OF AGRICULTURE



BULLETIN No. 323

Contribution from the Bureau of Plant Industry
WM. A. TAYLOR, Chief



Washington, D. C.



December 4, 1915

IMPORTANCE AND CHARACTER OF THE MILLED RICE IMPORTED INTO THE UNITED STATES.

By F. B. WISE,
Assistant in Grain Standardization.

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INTRODUCTION.

In the United States the annual production of rice has not been sufficient to supply the domestic demands for this cereal; hence, it has been necessary to augment the American crop by importing large quantities from abroad. The competition on our markets between the home-grown rice and certain grades of foreign rice has become a matter of vital importance to the rice producing, milling, and handling interests in Louisiana, Texas, Arkansas, South Carolina, and California. For successful competition those connected with the rice industry of the United States should have a knowledge of the quantity, quality, and condition of the rice imported and be familiar with the most common rice types of foreign origin. To secure information concerning the economic value of the rice imported, to study its quality and condition at the time of importation, and to determine the characteristics of the most important types of foreign rice found on American markets, an investigation of the importation of rice into the United States was made in the spring and summer of 1914. It is expected that the information secured will not only be beneficial to those connected with the production, milling, and handling of the domestic crop, but will also be of interest to the importers, dealers, and wholesale grocers who now handle foreign rice, and to rice consumers in general. The quantities of rice brought in are found to vary yearly

and to depend upon the prices prevailing, the growing and harvesting conditions existing throughout the rice-producing countries of the world, and the tariff and other shipping conditions under which the importations are made.

QUANTITY AND VALUE OF RICE IMPORTED.

Through the courtesy of the Department of Commerce the detailed list of rice imports shown in Table I was secured. It will be seen on examining this table that the quantity and value of imported rice have become greater from year to year, and especially is the increase noticeable in the milled rice when the total for the fiscal year ended June 30, 1914, is compared with that of 1912 and 1913. Table I shows that practically \$5,000,000 worth of rice was imported during the fiscal year ended June 30, 1914, an increase of about 60 per cent over the importation of 1913 and 100 per cent over that of 1912.

TABLE I.—Quantity and value of rice imported into the United States during the fiscal years ended June 30, 1912, 1913, and 1914, according to the countries from which shipped.

PART I.—UNCLEANED OR "BROWN" RICE (INCLUDING "PADDY" OR ROUGH RICE).

Exporting country.	1912		1913		1914	
	Quantity.	Value.	Quantity.	Value.	Quantity.	Value.
	<i>Pounds.</i>	<i>Dollars.</i>	<i>Pounds.</i>	<i>Dollars.</i>	<i>Pounds.</i>	<i>Dollars.</i>
Europe:						
France.....	833	7				
Germany.....					66,805	1,280
Italy.....	615	13			39,221	1,650
Netherlands.....					508,931	11,298
United Kingdom.....			56,000	1,307	120	9
North America:						
Canada.....	44,320	1,596	55,070	1,638	29,900	1,129
Mexico.....	285,384	9,911	963,738	33,934	411,897	18,016
West Indies.....			25	3		
South America:						
British Guiana.....					798,102	12,032
Asia:						
China.....	128,268	4,403				
Hongkong.....	20,220	503	3,185,195	74,920	576,525	17,415
Japan.....	47,998,624	1,601,946	47,519,298	1,788,279	52,013,918	1,845,349
British India.....					338,632	9,480
Total.....	48,478,264	1,618,379	51,779,326	1,900,081	54,784,051	1,917,658
Recapitulation:						
Europe.....	1,448	20	56,000	1,307	615,077	14,237
North America.....	329,704	11,507	1,018,833	35,575	441,797	19,145
South America.....					798,102	12,032
Asia.....	48,147,112	1,606,852	50,704,493	1,863,199	52,929,075	1,872,244

PART II.—COMPLETELY MILLED RICE.

Europe:						
Belgium.....			56,000	1,729	900	27
Denmark.....					220	10
France.....	6	1				
Germany.....	39,884	1,502	218,084	7,035	4,716,558	153,250
Greece.....	2,379	150	1,725	111		
Italy.....	1,817,925	65,308	1,239,353	47,186	1,421,615	54,072
Netherlands.....	2,401,257	88,128	2,521,070	98,440	48,407,957	1,632,584
Norway.....			200	20		
Spain.....	76,734	2,988	57,550	2,289	89,899	3,324
Switzerland.....					599	50
United Kingdom.....	4,586,094	118,119	3,631,443	107,436	4,871,248	136,844

TABLE I.—*Quantity and value of rice imported into the United States during the fiscal years ended June 30, 1912, 1913, and 1914, according to the countries from which shipped—Continued.*

PART II.—COMPLETELY MILLED RICE—Continued.

Exporting country.	1912		1913		1914	
	Quantity.	Value.	Quantity.	Value.	Quantity.	Value.
	<i>Pounds.</i>	<i>Dollars.</i>	<i>Pounds.</i>	<i>Dollars.</i>	<i>Pounds.</i>	<i>Dollars.</i>
North America:						
British Honduras.....			152	4		
Canada.....	13,734	656	7,337	526	411,413	12,268
Mexico.....	18,710	950	3,395	215	6,158	452
West Indies.....	1,472	64	18,379	526	2,522	114
South America:						
British Guiana.....					542	15
Asia:						
China.....	13,047,902	466,469	21,560,121	820,009	30,417,603	864,736
Chosen (Korea).....					42,294	1,306
British India.....	393,708	10,844	528,147	16,436	531,653	16,381
Dutch India.....					43,781	1,204
Hongkong.....	2,571,362	91,991	2,852,803	100,220	4,189,440	130,573
Japan.....	37,190	1,295	19,505	803	153,705	5,734
Siam.....					195,618	4,153
Turkey in Asia.....	57	4	215	20	240	9
Africa:						
British West Africa.....					33	2
Total.....	25,008,414	848,469	32,715,479	1,203,005	95,503,998	3,017,108
Recapitulation:						
Europe.....	8,924,279	276,196	7,725,425	264,246	59,508,996	1,980,161
North America.....	33,916	1,670	29,263	1,271	420,093	12,834
South America.....					542	15
Asia.....	16,050,219	570,603	24,960,791	937,488	35,574,334	1,024,096
Africa.....					33	2
Total, all rice.....	73,486,678	2,466,848	84,494,805	3,103,086	150,288,049	4,934,766

COUNTRIES FROM WHICH RICE IS IMPORTED.

Most of the rice imported into the United States is shipped from the continents of Asia and Europe. China and the Netherlands are heavy exporters of completely milled rice, while Japan leads in the uncleaned or "brown" rice business. Practically all rice received from China and Japan reaches the United States through the Pacific coast ports, principally San Francisco, Cal., and is mostly used to supply the demand in the Western States, where there are considerable numbers of Japanese and Chinese residents. The imports from other countries of North America were of little importance until 1914, with the exception of rough rice from Mexico, when Canadian dealers began sending in milled rice which had been imported by them in a "brown" or rough condition from Asia. The United Kingdom, with its great shipping interests, in 1913 ranked first among the European countries which export rice to the United States. During the following year, however, the Netherlands and Germany, where numerous large mills are established, furnished a major part of the rice imported from Europe. Italy and Spain, as producers and milling centers, also supply American dealers with rice in considerable quantities. The rice imported from European markets is practically all completely milled, and a large percentage

of it is coated. It enters the United States primarily through the ports of New York, Philadelphia, and Boston, from which points it is widely distributed.

DESCRIPTION OF RICE TYPES.

In the numerous samples secured for these investigations many types of rice were found. From the standpoint of total value the Japan rice was of first importance and was separated into four subdivisions, depending upon its mill finish. Other types of importance are the Chinese, Siam, Java, Bassein, and Patna, which get their names from the country or province in which they are grown. The color and luster of the rice of individual samples within each type vary considerably, and in other particulars the quality is not uniform in the types. The description of the rice types given in this bulletin, therefore, includes only those characteristics common to all samples of the type.

Rice of the Japan type has short and more or less rounded grains. Differences existing in the appearance and character of the rice, caused by varying methods of milling and by climatic influences upon the growing grain, make it necessary in commercial practice to subdivide rice of this type into four general classes. These subdivisions are (1) "brown," or the rice with only the outer hulls or chaff removed; (2) completely milled rice of a flinty texture and heavily coated with talc, calcium carbonate, or some white siliceous material resembling talc; and (3) completely milled rice of a bluish white color, semitranslucent, and very heavily coated with glucose and talc or some white siliceous mineral resembling talc. The rice of this third subdivision often has a slightly kidney-shaped grain and all samples collected of it were grown in Italy. (4) Glutinous Japan rice, completely milled. The rice of the samples belonging to this fourth subdivision which was handled in this investigation had a very soft or chalky texture and was opaque. Its shape is the same as other Japan rice described in the first and second subdivisions of this group, but it is smaller in size.

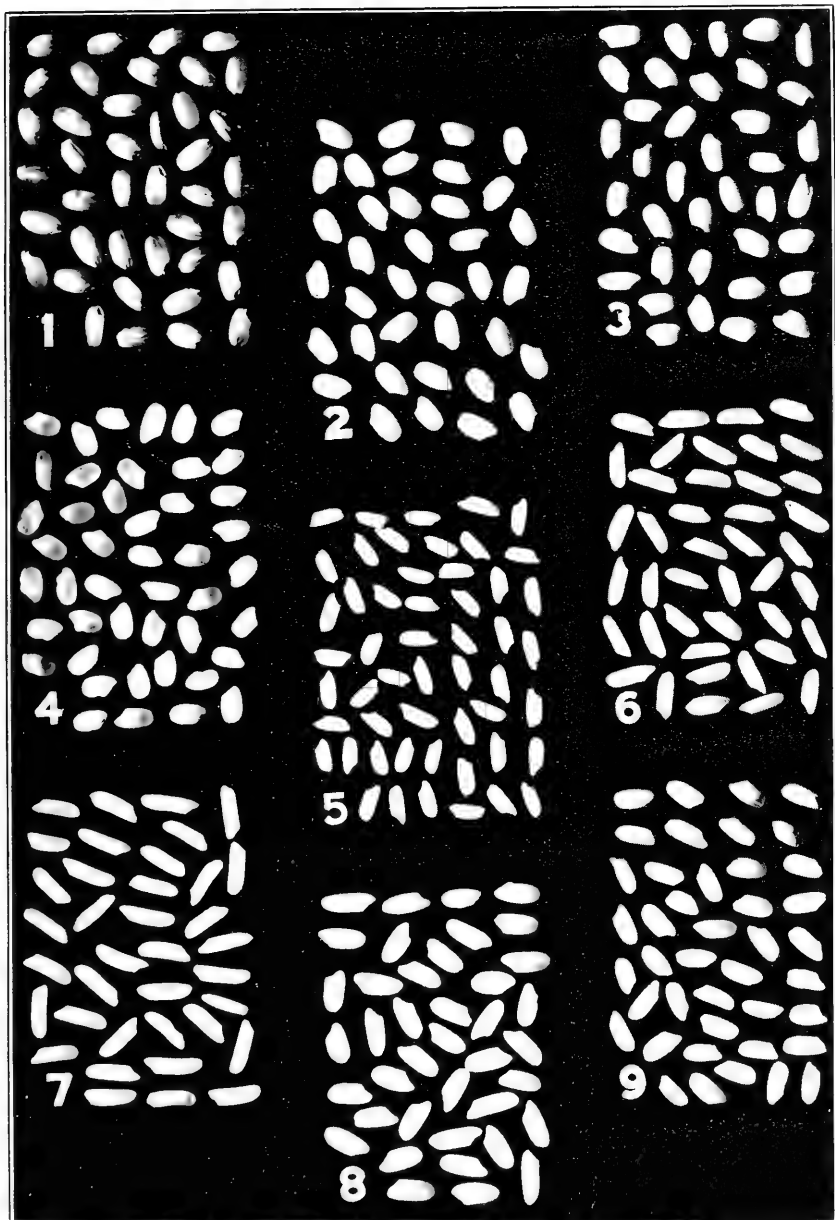
The Siam rice is generally of a flinty texture, and the grain is long and slender, with a relatively small germ.

The Chinese rice is of a white color, very flinty in texture, and of about the same shape as the Siam rice, but very much smaller.

The Java rice is of a white color and in shape is longer than the Japan rice and less rounded. Its germ is relatively large, and the grain is generally quite hard and flinty in texture.

The Bassein rice is very similar to the Java in shape, but slightly smaller in size, with a smaller germ and often a more chalky texture.

The Patna rice, which is comparatively white in color, is generally very flinty and heavily coated with glucose and talc. The kernels



WHOLE GRAINS OF THE VARIOUS TYPES OF RICE.

FIG. 1-3. Japan rice, grown in Japan. 1, "Brown"; 2, coated with tale; 3, glutinous. FIG. 4.—Japan rice, grown in Italy, coated with glucose and tale. FIG. 5.—Chinese rice, grown in China. FIG. 6.—Siam rice, grown in Siam. FIG. 7. Patna rice, grown in Patna, India. FIG. 8.—Java rice, grown in Java. FIG. 9. Bassem rice, grown in Bassem, India. (Natural size.)

are very long and very slender and have a bright luster, but otherwise they resemble the Siam rice.

A few samples of several other rice types, including "Rangoon," "Maulmein," and "Saigon," were secured. These types of rice are now of so little commercial importance in the United States that they are not described nor are the analyses of such samples tabulated in this bulletin.

Plate I shows whole grains of the various types of rice described.

MECHANICAL ANALYSES OF SAMPLES OF IMPORTED RICE.

Practically all of the samples of imported rice upon which this investigation was based were secured at the American ports of entry by officials of the Bureau of Chemistry. The samples and the information secured at the time of sampling were submitted by that bureau to the Office of Grain Standardization, where the mechanical analyses were made and the tabulating work was done.

Only those factors which directly concern the commercial grading or affect the market value of rice were considered in the analyses, and they were determined on a 50-gram portion of each sample. In making the size separation, the weighed portion of the sample to be analyzed was first shaken on a flat metal screen with round holes six sixty-fourths of an inch in diameter. The particles which passed through the screen were weighed, and the results, calculated to a percentage basis, are recorded in Table II in the column headed "Through No. 6 screen." The whole grains and broken particles which did not pass through the screen were carefully separated by

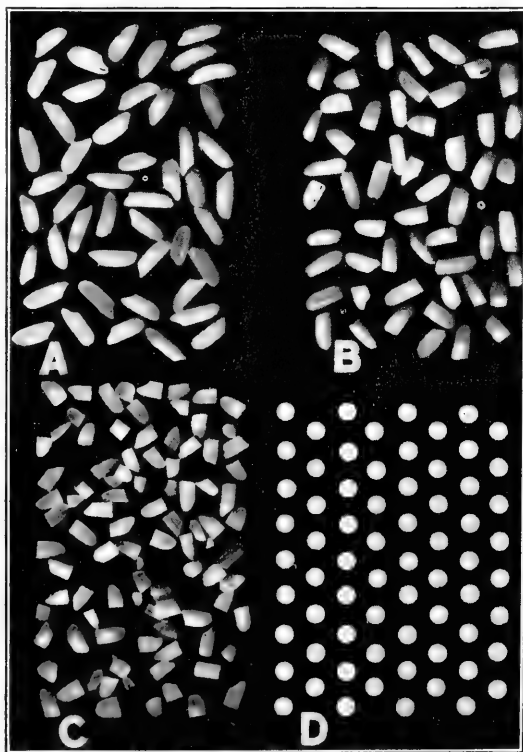


FIG. 1.—Whole and broken grains of Siam rice and a section of the screen through which they pass: A, "Whole grains;" B, "half grains;" C, broken particles which pass through a No. 6 screen with round holes six sixty-fourths of an inch in diameter, as shown in D. (Natural size.)

hand picking, weighed, and the results tabulated in the columns headed "Whole grains" and "Half grains," respectively.

Figure 1 shows the results from the size separation of a sample of Siam rice, with a section of the No. 6 screen used, showing the actual size of its openings.

TABLE II.—*Summary of results of mechanical analyses of samples of rice imported into the United States.*

Number of samples, type, and quality.	Weight per 1,000 grains.	Damaged rice.	Paddy grains per 100 grams.	Size separation.			Value per hundred-weight at point of shipment.
				Whole grains.	Half grains.	Through No. 6 screen.	
51 samples, Japan rice, brown:	<i>Grams.</i>	<i>Per cent.</i>	<i>Number.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	
Average.....	24.2	2.3	10.0	98.1	1.7	0.2	\$3.64
Maximum.....	29.2	4.4	68.0	99.6	6.0	1.0	3.98
Minimum.....	21.2	1.1	0	93.4	.2	0	3.04
4 samples, Japan rice, glutinous:							
Average.....	18.7	.3	0	85.1	14.0	1.0	-----
Maximum.....	20.2	.6	0	94.4	20.0	1.2	-----
Minimum.....	17.8	.1	0	79.2	4.8	.8	-----
8 samples, Japan rice, coated with talc:							
Average.....	20.6	1.0	0	89.7	8.4	1.9	-----
Maximum.....	22.4	2.0	0	94.4	12.8	3.6	-----
Minimum.....	17.6	.3	0	83.6	5.2	.2	-----
10 samples, Japan rice, grown in Italy:							
Average.....	20.4	3.2	.8	97.5	1.5	1.0	-----
Maximum.....	21.0	6.0	4.0	99.6	2.8	3.0	-----
Minimum.....	19.8	.4	0	95.2	0	0	-----
66 samples, Chinese rice:							
Average.....	12.7	.4	.2	70.8	26.0	19.0	3.06
Maximum.....	16.8	3.5	3.0	83.0	26.0	19.0	3.69
Minimum.....	11.8	.1	0	57.0	26.0	19.0	2.64
44 samples, Java rice:							
Average.....	20.5	1.1	.01	92.1	7.2	.7	-----
Maximum.....	23.6	5.6	2.0	98.4	22.0	4.0	-----
Minimum.....	17.8	.1	0	75.6	1.4	0	-----
65 samples, Siam rice:							
Average.....	18.1	1.5	1.1	71.4	20.4	8.3	-----
Maximum.....	19.0	4.0	10.0	88.4	42.0	32.6	-----
Minimum.....	14.4	.4	0	40.0	10.0	0	-----
4 samples, Bassein rice:							
Average.....	19.0	1.7	0	93.4	5.5	1.2	-----
Maximum.....	20.2	1.8	0	96.6	7.0	2.6	-----
Minimum.....	18.6	1.6	0	91.4	2.0	0	-----
11 samples, Patna rice:							
Average.....	18.5	.7	.1	73.8	20.6	5.5	-----
Maximum.....	20.2	1.8	2.0	93.0	40.0	22.4	-----
Minimum.....	17.6	.2	0	56.6	6.8	0	-----

CHEMICAL ANALYSES OF SAMPLES OF IMPORTED RICE.

Chemical analyses of single samples considered characteristic of the various imported rice types were made in the Bureau of Chemistry. The determinations made on each sample covered moisture, ash, ether extract, protein, and crude fiber. The results of these analyses are given in Table III.

TABLE III.—Results of chemical analyses of rice imported into the United States compared with the analyses of patent flour from hard spring wheat, hard winter wheat, and soft winter wheat, and with the analyses of "table grits" and unbolted meal made from white corn.

Type and description of sample.	Moisture.	Ash.	Ether extract.	Protein.	Crude fiber.	Calculated to a moisture-free basis.			
						Ash.	Ether extract.	Protein.	Crude fiber.
Japan:	<i>P. ct.</i>	<i>P. ct.</i>	<i>P. ct.</i>	<i>P. ct.</i>	<i>P. ct.</i>	<i>P. ct.</i>	<i>P. ct.</i>	<i>P. ct.</i>	<i>P. ct.</i>
Brown.....	11.52	1.22	1.92	6.75	1.10	1.33	2.17	7.63	1.24
Coated with talc or some siliceous mineral.....	12.21	1.31	.43	6.14	.41	1.49	.49	6.99	.47
Glutinous, uncoated.....	11.81	.79	.29	7.38	.37	.90	.33	8.37	.42
Grown in Italy; heavily coated.....	11.80	.55	.13	6.59	.36	.63	.15	7.47	.40
Chinese:									
Uncoated.....	12.06	.55	.20	8.06	.40	.62	.23	9.17	.46
Siam:									
Uncoated.....	11.81	.38	.21	7.06	.40	.43	.24	8.01	.45
Patna:									
Coated with glucose and talc or some siliceous mineral.....	11.97	.74	.18	8.06	.46	.84	.20	9.16	.51
Java:									
Uncoated.....	11.86	.40	.17	7.75	.40	.45	.19	8.79	.45
Bassein:									
Coated with glucose and talc or some siliceous mineral.....	12.33	.89	.25	7.19	.41	1.02	.29	8.20	.47
Hard spring wheat, patent flour ¹						.55	1.34	14.36	.....
Hard winter wheat, patent flour ²						.52	1.15	11.57	.....
Soft winter wheat, patent flour ³						.70	1.54	10.38	.....
White corn, table grits ⁴						.62	1.47	9.38	.....
White corn, unbolted meal ⁴						1.49	4.61	9.58	.....

¹ North Dakota Experiment Station Bulletin No. 89. 1910.

² Kansas Experiment Station Bulletin No. 202. 1915.

³ Department of Agriculture, Chemical Division Bulletin No. 1. 1883.

⁴ United States Department of Agriculture Bulletin No. 215. 1915.

The ash, ether extract, and crude fiber of the "brown" or partly milled Japan rice are very high as compared with the same constituents in other types of rice and other subdivisions of the Japan type. This indicates that in the ordinary method of milling rice, where practically all of the bran coat is removed, the percentage of these constituents is materially decreased.

The Japan rice marked "coated with talc," which has a very powdery surface, is shown on analysis to yield 1.49 per cent of ash. This is an exceedingly large ash content for milled rice, as shown when it is compared with that of uncoated milled rice of the same type grown in the United States, the ash content of which is only 0.51 per cent. The glutinous Japan rice, which does not seem to be milled as deeply as the other milled rices, contains a relatively large quantity of ash and also shows a relatively high percentage of protein. Of the other rice type, it is shown that as a rule the addition of a coating material increases the ash content but has little effect upon the amounts of other constituents.

In studying the protein of the various types of rice many factors seem to be of importance. Chinese white rice, which has a very small and very flinty kernel, contains in a water-free sample 9.17 per cent of protein; and Patna rice, which shows indications of severe milling, also has a high protein content. The climatic and, possibly, the soil conditions under which rice is grown seem to exert as great an influence upon the quantity of its protein as does the method or severity of milling. By comparing the protein content of the first with that of the second subdivision of the Japan rice type, as shown in Table III, it is seen that only 0.64 per cent of this constituent is scoured off in the process of milling. Even though the milling of rice does not remove the major part of its protein, as is commonly supposed, there is in the milling of a given quantity of the grain a total loss of this expensive food constituent which should be considered. Completely milled rice can not be regarded as a balanced ration, simply because a large part of the original protein remains in the starchy endosperm of the kernel after milling. In judging a food the protein content is, of course, an important factor, but it must be considered in connection with various other important factors, such as ether extract and, to a less extent, ash. As previously mentioned, the milling of rice reduces its ash content very materially, and the ether extract, the greater part of which is in the germ of the kernel, is decreased from over 2 per cent to about 0.2 or 0.3 per cent, which is almost a negligible quantity. The slight losses in protein and in minute quantities of a substance called "vitamine," together with the very great loss in ether extract and ash, which result from the modern methods of milling rice, tend to greatly lessen its food value and to yield by-products containing large quantities of valuable constituents of human food.

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BULLETIN No. 324



Contribution from the Bureau of Plant Industry
WM. A. TAYLOR, Chief

Washington, D. C.



December 22, 1915

COMMUNITY PRODUCTION OF DURANGO COTTON IN THE IMPERIAL VALLEY.

By ARGYLE McLACHLAN,

Scientific Assistant, Office of Western Irrigation Agriculture.

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INTRODUCTION.

Cotton growing in the irrigated valleys of southern California and Arizona, which was begun in 1909, has already become of great commercial importance. The gross income from the cotton industries in these two States in 1913 exceeded \$1,400,000. In 1914 it was over \$2,000,000, even under the poor market conditions of that season.

The United States Department of Agriculture has given assistance in extending the growing of long-staple cotton in the southwestern irrigated valleys, and in 1910 introduced Durango long-staple cotton in the Imperial Valley. This variety, which bears fiber from $1\frac{3}{16}$ to $1\frac{1}{4}$ inches in length, yields as well as short-staple varieties and brings better net returns. In 1913 the Durango crop amounted to 6,000 bales; in 1914, to 8,000 bales.

Cotton growing on a community basis—the growing of one sort of cotton in a community—with Durango cotton as the variety advocated, now has the support of those cotton growers of the Imperial Valley who are associated in a cooperative organization.

Many important problems are yet to be worked out to place cotton growing on the profitable basis it should assume under the local conditions of production, handling, and marketing. These problems should be frankly recognized and solved wisely if the cotton industry is to continue an important feature of the agriculture of the Imperial Valley.

The evolution of this particular cotton industry is toward the growing of one superior variety of long-staple cotton exclusively. Of the problems connected with the industry, possibly the most important at this time is that of establishing a consistent production of large average yields of high-quality fiber.¹ The full possibilities of the industry will most quickly become realized by directing community effort toward the stabilization of long-staple cotton.

It is proposed in this paper to explain what is meant by stabilization, its bearing on the different interests involved in the production and marketing of long-staple cotton, and the manner in which the stabilization can be brought about. A discussion of the development of the industry is included, for the purpose of making clear the steps that have been taken toward the adoption of a long-staple variety.²

HISTORY OF THE INDUSTRY.

IMPERIAL VALLEY IN CALIFORNIA AND MEXICO.

The Imperial Valley is a portion of the delta of the Colorado River which extends some 40 miles on either side of the international boundary between the State of California and Lower California, Mexico. Cotton growing, like other agricultural enterprises, is practically continuous across the boundary. The irrigation system carrying water into California comes through Lower California, and the irrigation water for both sections is taken from the same main canal. Quarantine measures to guard against infestation by destructive insects are administered by California State and United States Federal authorities, and are designed to give these officers reasonable control over shipments of seed to and from Mexico, as well as into California from the Eastern States. The interests of cotton growers in Cali-

¹ See the article entitled "Cotton Improvement on a Community Basis" in the Yearbook of the United States Department of Agriculture for 1911.

² Investigations incident to establishing the long-staple cotton industry in the Southwest are carried on under the general direction of the Southwestern Cotton Culture Committee. The following is the personnel of the committee:

C. S. Scofield, Agriculturist in Charge of Western Irrigation Agriculture, is chairman of the committee and, in addition, has charge of those phases of the work which involve cooperation with the United States Reclamation Service. The author of this bulletin has been Mr. Scofield's field assistant in this work.

W. T. Swingle, Physiologist in Charge of Crop Physiology and Breeding Investigations, has charge of those phases of the work which involve cooperation with the Office of Indian Affairs. The Cooperative Testing and Demonstration Garden at Sacaton, Ariz., is under Mr. Swingle's direction.

O. F. Cook, Bionomist in Charge of Crop-Acclimatization and Cotton-Breeding Investigations, conducts investigations of the factors involved in the acclimatization of different types of cotton in the Southwest and of the relation of these factors to cultural methods. He has also been active in developing the idea of community cotton growing as a means of maintaining uniform varieties.

T. H. Kearney, Physiologist in Charge of Alkali and Drought Resistant Plant Investigations, has charge of the breeding work with Egyptian cotton and of investigations of the effects of alkali and other soil conditions upon the production of this crop.

C. J. Brand, Chief of the Office of Markets and Rural Organization, has charge of the investigations in classing, marketing, and transportation.

fornia and in Lower California are thus identical in many important particulars. The Mexican crop, largely increased in the past two years, has been ginned and marketed in California towns. As the gins do not report the Mexican crop separately, the statements and tabulation involving acreages and yields given later refer to cotton from the whole of the Imperial Valley.

EARLY PLANTINGS.

The first commercial crop of cotton, grown in 1909, was preceded by numerous test plantings. As early as 1902 a planting of Egyptian cotton was made by the Department of Agriculture at Calexico, Cal. This cotton grew luxuriantly and reproduced itself from the old stumps for a number of years. Settlers from the older cotton States planted a few seeds of Upland cotton on their ranches, and it was found that these plants thrived in the new country. It is probable that cotton plants were grown in the valley each season from the time irrigation water was brought in (1901) until the industry was definitely launched in 1909. Earlier plantings of cotton in other irrigated sections of southern California¹ indicated that success with cotton in the Imperial Valley was to be expected.

Half an acre of cotton near El Centro, Cal., planted in 1906 and ratooned in 1907 yielded well both seasons. This plat attracted much attention and had an important bearing in creating confidence in cotton as a crop for the valley and in crystallizing sentiment for cotton growing. A number of individuals made small test plantings in 1908.

Though the cultivation of cotton under irrigation conditions was little understood by the farmers in 1909, it had been clearly demonstrated (1) that seedling cotton yielded well and (2) that cotton could be ratooned or grown from old roots which lived through the preceding winter. The ratooning of cotton is here mentioned because of its bearing later on the progress of the industry.

EXPANSION OF THE INDUSTRY.

The first commercial crop, that of 1909, was grown on 450 acres, averaging a little more than three-fourths of a bale per acre. The 350 bales of the 1909 crop sold on a high market, much of it at 14 cents a pound. This proved a great incentive to more extensive planting in 1910.

In 1910 the crop amounted to 4,000 bales, and each year since then the total crop has been more than double that of the preceding year, with the exception of the 1912 crop. This did not equal the 1911 crop in size, due largely to the depressing effect of the low prices obtained

¹ Hilgard, E. W. Cotton in California. A bit of history of cotton planting in this State. In Cal. Cult., v. 40, no. 23, p. 691. 1913.

during the crop year of 1911. The 1913 crop, however, was three times as large as that of 1912. In 1914 approximately 43,000 bales were produced on 66,000 acres.

GINNS, OIL MILLS, AND COMPRESSES.

The ginning equipment has kept pace with the expansion of the industry. The temporary equipment used for ginning the 1909 crop was replaced in 1910 by a complete ginning plant at each of five towns. By 1913 the number of gins had been increased to eight, and in 1914 more than double this number had been erected, in order to take care of the largely increased crop. The 19 gins now operated are owned by three separate companies. This equipment was more than sufficient to handle the 1914 crop. Half of these gins are located at Calexico, the border town, in order to handle the Mexican crop, which is all brought there for ginning.

The first oil mill was erected at El Centro in 1911. In 1914 two more mills were erected, at Calexico, one of them a cold-compress mill. The capacity of the oil mills has been expanded somewhat beyond the present requirements of the industry.

VARIETIES GROWN.

SHORT-STAPLE COTTON.

Short-staple cotton was grown almost exclusively for the first three years after the industry was started. Big-bolled varieties of Texas cotton were most popular, the Triumph and Rowden varieties predominating. The Triumph (Mebane's) cotton has now come to be the short-staple variety usually planted. This is an indication of the progressive development the industry has been undergoing from the beginning, as Triumph cotton is an excellent variety for the Imperial Valley conditions. It yields well and produces uniform fiber from 1 inch to $1\frac{1}{16}$ inches in length.

A number of short-staple varieties with small bolls and ununiform fiber, some of them quite inferior, have been tried on extensive acreages. The use of these varieties has been, as a rule, soon abandoned, but in crossing and mixing with seed stocks of good short-staple varieties they have left a damaging impress. The Georgia cotton introduced in 1909 and a variety called "World's Wonder" introduced in 1910 are examples of such inferior varieties.

Many of the growers have acquired all their experience in cotton growing in the Imperial Valley. These men have approached the problem of cotton growing under irrigation with open minds, which doubtless accounts in large measure for the success of the new industry. If better varieties and better cultural and marketing methods have become available, they have made use of them. It was in this spirit that their growers' cooperative ginning company

invited representatives of the Department of Agriculture to inspect their fields in the fall of 1910 and advise them as to which one of the varieties being grown was the best. The inspection included numerous fields of Mebane's Triumph, Georgia, World's Wonder, and one or two small fields of Allen's Long-Staple cotton. Long-staple cottons were not popular at that time, as only the small-bolled varieties were known to growers in the valley. A choice had to be made as to the best short-staple variety. When it was advised that seed of the Triumph variety be retained for planting and that the seed of all other varieties be sent to the mill for manufacture into oil, the advice was acted upon, and early in 1912 a further supply of Triumph seed was imported from Texas. This was a wise step, as the seed of the 1909 crop, used for planting in 1910, had become badly mixed. Since that time commercial plantings of short-staple cotton have been practically confined to the Triumph variety.

EGYPTIAN COTTON.

In 1909 it was determined by the Department of Agriculture that an improved acclimatized variety of Egyptian cotton was a success as a field crop under irrigation in southern Arizona and southern California. In 1912 a number of persons in the Imperial Valley were sufficiently interested to plant small acreages (5 to 10 acres) of the acclimatized Yuma variety.¹ While a few plantings yielded excellent fiber and as much per acre as short-staple cotton, proving that Egyptian cotton could be successfully raised in the Imperial Valley, the test also demonstrated that labor conditions in that valley, as well as the presence of Upland cotton, precluded the establishment of Egyptian-cotton growing there at that time.

LONG-STAPLE UPLAND COTTON.

The future success of the cotton industry in the Imperial Valley is apparently contingent upon the extension of the production of long-staple Upland cotton. Durango cotton, a 1 $\frac{1}{4}$ -inch Upland long-staple cotton,² introduced into the Imperial Valley by the Department of Agriculture in 1910, was planted on about 200 acres in 1912, at the same time that the first planting of Egyptian cotton was made. Previous to 1912 it had been demonstrated that the Durango cotton was well suited to local conditions and that it yielded as well as short-staple cotton. As grown under irrigation with an adequate and

¹ Kearney, T. H. Breeding new types of Egyptian cotton. U. S. Dept. Agr., Bur. Plant Indus. Bul. 200, 39 p., 4 pl. 1910.

Kearney, T. H., and Peterson, W. A. Egyptian cotton in the southwestern United States. U. S. Dept. Agr., Bur. Plant Indus. Bul. 128, 71 p., 2 fig., 5 pl. 1908.

² Cook, O. F. Durango cotton in the Imperial Valley. In U. S. Dept. Agr., Bur. Plant Indus. Cir. 111, p. 11-22, 5 fig. 1913.

McLachlan, Argyle. Culture of Durango cotton in the Imperial Valley. In U. S. Dept. Agr., Bur. Plant Indus. Cir. 121, p. 3-12. 1913.

uniform water supply, Durango cotton possesses a high degree of uniformity in length of staple. These qualities of yield and uniformity of the Durango variety have warranted its general extension in the Imperial Valley, which has progressed rapidly since 1912.

Table I shows the total cotton crop, in 500-pound bales, of the Imperial Valley for the years 1909 to 1914, inclusive, the different sorts being specified. These figures are merely estimates, as no absolutely accurate data are available.

TABLE I.—*Cotton crop of the Imperial Valley, 1909 to 1914, inclusive, in bales.*

Year.	Short staple.	Long-staple Upland.	Egyptian.	Total crop.
1909.....	350	.....	.....	350
1910.....	4,000	.....	.....	4,000
1911.....	8,997	3	.....	9,000
1912.....	6,950	150	100	7,200
1913.....	15,500	6,000	.....	21,500
1914.....	34,900	8,000	100	43,000

A number of other varieties of long-staple Upland cotton have been tried, either experimentally or in field plantings,¹ but none of these varieties has proved as well suited to the conditions as the Durango cotton. Besides its superiority over other long-staple Upland varieties in greater uniformity of fiber and in larger size of boll, Durango cotton possesses cultural features which make it well adapted to irrigation farming in the Imperial Valley.¹

ECONOMIC IMPORTANCE OF LONG-STAPLE COTTON.

When properly grown, Durango cotton has been found to give better net returns than short-staple cotton; that is to say, in equal yields of a bale or more per acre the Durango variety pays better than short-staple cotton, and it may be further stated that it is economically unsound practice, as well as unnecessary, to grow less than a bale of cotton to the acre in the Imperial Valley. Of some 600 growers in the Imperial Valley in 1914, probably 150 were growing Durango cotton.

PROGRESS DUE TO ORGANIZED EFFORT.

The chief purpose of this paper, in showing as clearly as possible how one community has been solving the problems of a developing agricultural industry, can best be served by a rather detailed discussion of the history of the industry. It can be understood from what has already been stated that community organization has been largely responsible for the important advances made in the choice of superior varieties and in the attempted elimination of inferior ones.

This is an example of the practical application of the plan of improving cotton production through community action.

¹ Cook, O. F. Op. cit.

As progress in the industry can be expected to result chiefly through the efforts of organized growers, an account is given of the different organizations that have taken part in the evolution of the industry under discussion. There have been three cooperative organizations of cotton growers in the Imperial Valley, which have had much to do with the progress of the industry.

In 1910 the growers formulated and put into operation a plan for a cooperative ginning and oil-mill company. This company erected and operated the first permanent ginning plant and partly financed the erection of an oil mill. That the company was finally taken over by private interests and that the oil mill was completed by them is no reflection on the plan as conceived by its originators. An outline of the plan is given because of the general interest it may assume in connection with cotton growers' cooperative marketing, ginning, and oil-mill companies.

The organization was established to secure community credit. A stock company was formed, the stock being valued at \$15 a share. Bona-fide cotton growers subscribed for this stock, taking a share for each 2 acres planted or to be planted to cotton. A note was given the company for the value of the stock subscribed for, payable in cotton seed on the basis of \$15 per ton. As each acre yielding a bale of cotton yields also half a ton of seed, it was expected that seed from each 2 acres of cotton would pay for a share of stock at the end of the first crop year. The note was guaranteed by a crop mortgage, written to include the crop of the succeeding year if the note was not fully paid the first year.

The financing was done through southern California banks, and corporation notes were given, indorsed by each director, stock notes and crop mortgages being attached as collateral security. Obligations of more than \$100,000 were assumed by the cooperative company. Had economy been used in carrying out the plan there seems to be no reason why it should not have been successfully consummated.

COOPERATIVE COTTON HANDLING.

The Imperial Valley Cotton-Growers' Exchange, organized early in 1912 and operated during the marketing seasons of 1912 and 1913, was the first successful attempt of the growers to work cooperatively in marketing the crop. This organization functioned purely as a warehousing and marketing association, though it was incorporated to engage in all lines of activity touching the cotton industry, including ginning and the manufacture of oil. It was successful in marketing the 1912 crop of its members, mainly short-staple cotton. It bought and sold cotton successfully and secured for its members better returns for their cotton than could have been realized with only private buyers in the field. The exchange did not buy extensively,

but there is no doubt that by standing ready at all times to engage in buying and to pay full prices it injected into the local situation an effective stimulus to maintain prices at the highest possible level. Yards for warehousing and insuring the baled cotton of members were operated by the exchange at different points in the valley.

The expense of operating the exchange was provided for by a fixed charge on each bale handled. Through the operations of the cooperative exchange in 1912 much was learned about marketing, several outlets for cotton were secured, and confidence was created in the cooperative marketing plan.

In the following season (1913) the exchange functioned mainly in the marketing of long-staple cotton, fully three-fourths of the cotton handled being of this class. More private buyers had come into the valley, so that the competition for short-staple cotton was sufficiently keen to make it unnecessary for the exchange to enter that field. Doubtless, the understanding on the part of the buyers that the exchange stood ready to buy short-staple cotton had some influence on the local market. As a marketing agency for long-staple cotton the exchange proved its value and must be largely credited with insuring the continuance of the Durango cotton industry in the Imperial Valley in 1914. Under the practices pursued by private buyers it is improbable that long-staple cotton could have secured a foothold in the community. Methods of buying cotton which depend for profit on the ignorance of the producer as to the value of his product find greater range of opportunity when applied to long-staple cottons, which possess more factors of value than does short-staple cotton.

While the exchange was successful in marketing membership cotton, the plan of financing, which was the same as in 1912, provided inadequate funds for meeting the expenses in 1913. Added charges assessed against the cotton were sufficient to finance the actual operations, but a deficit resulted from heavy reclamations on some of the cotton, which was all shipped out in so-called "hog-round" lots, that is, without classification.

In 1912 the exchange handled 2,800 bales. In 1913 the organization included 139 members and handled about 5,000 bales.

The financial reliability of the organization was well tested in its warehousing and marketing activities. On each bale of cotton stored in the exchange yards under bonded management and insured, the exchange issued a warehouse receipt and made arrangements for loans at a reasonable rate of interest through Los Angeles and local banks.

From \$40 to \$50 per bale were loaned on warehouse receipts, so that in 1912 the exchange stood responsible for loans to its members aggregating fully \$100,000, and in 1913, for more than double that

amount. The value of cotton marketed in 1912 was about \$150,000 and in 1913 something over \$300,000.

Sales were made either through cotton brokers by consignment or direct to manufacturers. In case of consignment, arrangements were made for an advance from the factor of an amount sufficient at least to take up the bank loan and release the warehouse receipts, in order to permit shipment by the association. On the sale and delivery of the cotton by the factor final settlement was made. In direct sales samples were submitted to users, the cotton they purchased being paid for on shipment by sight draft attached to the bill of lading.

A LONG-STAPLE COTTON GROWERS' ASSOCIATION.

The Imperial Valley Cotton Growers' Exchange operated during both seasons (1912-13) with very limited capital. The charge assessed was too low to cover operating expenses in 1912 and was not increased until late in the season of 1913. The larger volume of business in sight the second year made any increase appear unnecessary. In spite of this fact the exchange completed both seasons with operating expenses fully paid, the first season by the make-shift of buying and selling cotton, and the second season by using the same methods and by making added charges per bale on such cotton as was marketed late. This was not a satisfactory arrangement, because of the possible danger to a cooperative organization of engaging in the cotton-buying business and because of the loss of confidence that might result from this practice and also from trying to operate on a financial basis requiring extra assessments against some of the cotton in order to cover running expenses. To perpetuate the life and usefulness of the organization these practices had to be done away with. Furthermore, the exchange in 1913 had served mainly as the necessary channel for marketing Durango cotton, its work in marketing short-staple cotton being only incidental.

The necessity for a nonprofiting long-staple cotton growers' association, financed on a substantial self-supporting basis, was quite evident to leading members of the exchange. Therefore, early in 1914 a plan was developed for the reorganization of the exchange on (1) a long-staple, community cotton-growing basis, (2) as a nonprofiting cooperative association, and (3) with financial arrangements providing funds adequate to cover all marketing operations. Some elements of this plan had been included in a proposed reorganization scheme outlined in the spring of 1913, which was not carried through because of lack of sufficient interest among the members. The plan as finally worked out represented the ideas of many of the best cotton growers in the Imperial Valley. An organization was finally effected in the summer of 1914.

In addition to the need of a cooperative selling agency to insure the growers full returns for long-staple cotton, there is an equally pressing requirement for the activity of a growers' organization in connection with the maintenance of a supply of pure seed and the insistence upon intensive cultural practices.

The Imperial Valley Long-Staple Cotton Growers' Association was organized on a plan which guarantees that its operations shall be adequately financed by the initial charge per bale. It arranges for the warehousing and insuring of the baled cotton and sells the product of its members on instructions from them, rendering the members a full account of the transactions. All cotton is sold on classified samples, and reclamations have been practically nil on sales of over 8,000 bales in marketing the 1914 crop. The association has cooperated with the Department of Agriculture in the maintenance and distribution of pure Durango seed.

STABILIZING LONG-STAPLE COTTON.

Stabilization, the continuous production of a crop with a fixed high quality of fiber, is the great problem now confronting the cotton industry in the Imperial Valley, as well as in many other sections of the cotton belt.

In actual application to the long-staple cotton industry, stabilization means the establishment of such practices in the growing and handling of cotton as will bring about the full realization of all the possibilities of the industry. It means the production of the one best variety of cotton throughout the community. It requires community action to insure an adequate supply of pure seed. In ginning, it means turning out a smooth sample without defects resulting from careless mechanical handling. Once the community has established a reputation for producing consistently a high quality of cotton, the problem of satisfactory marketing is greatly simplified. To the manufacturer who avails himself of the opportunity, it means the assurance of an annual supply of the kind of cotton he requires.

The problems in stabilization touch all interests concerned with the cotton industry. The cotton grower, the banker, the merchant, the ginner, the buyer, and the cotton manufacturer are all vitally interested, as they will all share in its advantages to a greater or lesser extent and should therefore contribute to its realization.

THE GROWER AND STABILIZATION.

The most important figure in the cotton industry is the cotton grower. His prominence entails responsibility, as it is by the growing of marketable cotton that the most effective step toward stabilization will be taken.

The grower should produce the largest crop possible on his acreage, because of the high proportion of fixed charges.

In addition to producing a big crop the grower must have it picked free of trash and ginned carefully, so that he will have smooth, undamaged cotton in the bale.

A good formula for the Imperial Valley grower to put into practice in doing his share toward stabilizing the industry can be stated in a few words: Plant good seed of the Durango variety, produce a bale or more per acre, and pick it carefully.

The production of a bale or more per acre of good middling cotton will be realized by growers only by the application of the best cultural and harvesting practices. These practices are listed below:

- (1) Thorough leveling of the land, so that water can be applied uniformly.
- (2) The maintenance of proper tilth conditions in the soil. This includes irrigation previous to planting, to get the soil into good, moist, planting condition.
- (3) The use of pure Durango seed.
- (4) Careful preparation of the seed bed.
- (5) Planting not later than early May.
- (6) Securing and maintaining a full stand of plants.
- (7) Thinning the plants by the single-stalk method¹ when the plants are 6 to 10 inches high and leaving them 8 to 10 inches apart in the row. This method has been found to increase the earliness and the yield.
- (8) Infrequent early irrigations, to guard against the overluxuriance of vegetative growth and to establish deep rooting.
- (9) Thorough and careful irrigation after flowering begins, to insure the normal growth of the plant and bolls and the steady setting of fruit.
- (10) Continued shallow cultivation, following each irrigation, as long as it is possible to get a horse between the rows.
- (11) Continued irrigation in the fall, in order to mature the late-summer and early-fall setting, which is the heaviest of the fruiting season.
- (12) Clean picking, to exclude leaves and other trash.
- (13) Careful ginning, to preserve the character and grade of the fiber.

With the exception of two items, this program has to do entirely with the culture of the crop, on which the grower must expend his intelligence and energy.

In the maintenance of pure planting seed, a basic necessity, he has the assistance of the long-staple cotton association, which has undertaken a plan to provide annually a large quantity of first-class planting seed for the industry.

To plant poor seed and spend a season growing a large crop of inferior fiber is a great dissipation of energy and represents a real loss of money. A large crop is synonymous with high quality only if good planting seed is used. With mixed seed the fiber is sure to show inferiority, even if a large crop is grown.

To preserve the quality of the fiber he has grown and to insure a good grade, the grower must have the cooperation of the ginner or else have his ginning done by the association.

¹ Cook, O. F. Single-stalk cotton culture. U. S. Dept. Agr., Bur. Plant Indus. [Misc. Pub.] 1130, 11 p., 12 fig. 1914.

Just as the growing of a large crop of uneven fiber from inferior planting seed, so ginning of a kind which injures well-grown fiber represents a waste of value. There is loss to the grower in both cases, but in either case his loss is not represented by a corresponding gain to anyone else. It is pure waste. To avert this waste under present ginning arrangements the growers must have the cooperation of the public ginner, so that the full value of the fiber may be preserved in the ginned and baled cotton.

RATOONING SHOULD BE DISCOURAGED.

In connection with the part the grower must play in assisting to bring about the stabilization of long-staple cotton, it should be emphasized that the ratooning of cotton, i. e., growing the crop from stumps of the previous season's planting, should be discouraged. This practice, which was supposed to save the expenses of preparation of land, seed, and planting, has been found to result in loss rather than in gain.

The ratooning of short-staple cotton in the Imperial Valley in previous seasons led to extensive ratooning in 1914, as ratooned short-staple cotton apparently produced as well as seedling cotton and the product had not been discriminated against in the market. Durango cotton on approximately 4,000 acres was ratooned in 1914, with the result that practically all the crop from ratooned fields was ununiform in fiber and very low in grade, and consequently it went on the market with the certainty of bringing a reduced price. While some yields of both were good, seedling Durango cotton probably surpassed in yield the ratooned Durango, although authentic records of comparative yields are not available. Much short-staple cotton also was ratooned, and the crop, as in the case of Durango, was found to be decidedly inferior in quality and value to seedling cotton.

THE GINNER AND STABILIZATION.

The ginner is interested in a stabilized industry because of his large investment in his plant. To know that he will have sufficient cotton to gin to pay him a dividend is of great importance to him. He can well afford to spend time and energy to see that the growers' product is brought to the marketing stage in the best possible condition so far as his handling of the cotton is concerned, since on the success of the grower depends the size of the crop.

Smoothly ginned high-grade cotton sells quickly and at a premium. To get this premium for high-grade fiber is not only essential to the stabilization of the cotton industry, but to the life of the industry as well. For the ginner to take pains to see that the full value of the fiber is preserved in the bale turned out by his gin is a form of insurance for his investment.

ORGANIZED GROWERS AND STABILIZATION.

One of the chief functions of a cooperative association of growers is to coordinate the activities of the grower, the buyer, the manufacturer, and the banker, and establish a condition of mutual confidence among all the interests concerned with the production and use of cotton.

The Long-Staple Cotton Growers' Association is possibly the greatest single aid to the stabilization of the long-staple industry. To realize fully its usefulness as a stabilizing agency it must further actively all that is best for the industry and for the grower. It must persist in the maintenance and distribution of clean, well-selected planting seed, and must develop local talent to assume the work of roguing fields for the maintenance of seed supplies.

The association may be expected to extend its activities to the solution of financial problems affecting the grower, as it is the logical agency to adjust crop loans in the interest of the grower; also warehousing and insurance rates, freight rates, and other financial matters of general interest.

A further function of the association which should not be neglected is the proper use of publicity in discussing the problems of the industry, in order to keep the grower informed of matters of interest to him. It must also do pioneer work in the advocacy of desirable new practices in culture. The exercise of its agricultural functions will contribute to its influence as a stabilizing agency.

COMMUNITY COTTON GROWING.

The most efficient stabilizing principle for which an association of growers can stand is the advocacy of one variety of long-staple cotton for the whole industry, the community cotton plan already referred to.

The growing of one superior variety of cotton throughout the Imperial Valley, involving the elimination of all other varieties, will greatly simplify the problem of securing pure planting seed. This is the most practical way to guard against deterioration from mixing with inferior varieties. Only one sort of cotton going into the trade, and that a superior variety, will be the most effective advertisement the industry can have.

Community cotton growing, through its creation of new common interests, may be expected to result in the more general application of intensive methods of culture.

ONE VARIETY SHOULD BE GROWN PERSISTENTLY.

Community cotton growing implies persistence in the exclusive use of one variety. The continued growing from year to year of the same kind of cotton will have a most important bearing on the

facility with which the crop is marketed; it will also have much to do with the price received for the cotton. It requires several seasons of intelligent business management to introduce and establish with the trade a long-staple cotton from a new locality. After the confidence of users has been gained and their interest has become established through reasonable expectation of getting the same high-quality cotton annually from the same center, it is quite probable that great loss to the growing industry would result through any change of varieties. From time to time there will come reports of enormous yields and big returns received from sorts of cotton other than the one grown in the community, but such reports, which are most frequently unauthenticated rumor, should not be permitted to unsettle the basis of the local industry. Because of the distinct advertising value that attaches to the reputation of a superior article the most good will result from the consistent building up of a valuable specialty.

CONTINUITY OF OPERATIONS.

Continuity of activity by the association is essential to the realization of its greatest efficiency as a stabilizing agency. To limit the activity of the association to the marketing season, from September 15 to March 15, would occasion a great falling off of interest at the end of one marketing season, which would necessitate a campaign for its revival at the beginning of the following season. Much of the momentum acquired during the marketing season would be lost during the suspension of activity in the growing season. In order to assume its full function toward the grower and the community, the association can not afford to interrupt its activity in this manner.

Marketing is the function of the association most readily understood by the public. There should be no illusion, however, on the part of the directorate or management as to marketing being the sole function of the association.

Close and sensitive contact with the members of the association should be maintained throughout the growing season by the management. The condition of every field of association cotton should be on record after actual inspection. If, for instance, a better water supply is required in any district, it is quite possible that the association management can do much to adjust the difficulty promptly, so that the fields may not suffer from drought. The interest the association can show in the growing of marketable cotton by its members will inspire confidence in the organization.

It is not proposed to outline a program of work to engage the association during the summer months, but rather to indicate the importance to the association of the continuity of activity. In actual operation many opportunities will suggest themselves to the man-

agement as important to follow during the growing season in order to provide the association with marketable cotton.

THE BANKER AND STABILIZATION.

The stabilization of the long-staple cotton industry should enlist the support of the banker, because cotton on a standardized basis, with one variety grown intensively, means the best there is financially in the cotton industry for the community. Durango cotton grown from pure seed provides an exceptionally good basis for crop loans; such cotton will command a good premium in the market and is thus first-class collateral.

Good business demands the elimination of the precarious elements from agricultural practices as far as possible. Sentiment for the general production of large yields and for the proper handling of a superior class of cotton can be fostered largely by the banker. Furthermore, the growing of cotton of known high quality does away with the risk attending an industry based on cotton of an unknown or inferior quality. To the grower the raising of cotton of unknown or inferior quality represents waste; to the banker, unnecessary risk. It is of economic interest to the banker to understand the nature and importance of pure planting seed; also to know where it is obtainable and that his patrons are taking the precaution of planting the best seed in order to provide his bank with reliable collateral.

It is of no less importance that the banker take a constructive interest in intensive culture, in order to further the production of maximum quantity and quality. A man growing but half a bale of cotton per acre may be a safe patron because of his innate honesty, but his business is worth little to the bank. Intelligent discussion of the matters of variety, good planting seed, and intensive culture by the banker financing his crop will go far to make the farmer not only a prosperous but a profitable patron.

It is good business for the banker to encourage the stabilization of the cotton industry, since a bale of high-quality cotton to the acre means good deposits, while a half bale per acre of any sort of cotton means the bare payment of loans.

Stabilization would make it possible for the banker to finance the patron's operations, so that the patron might meet all his expenses during the growing season by credit extended by the bank. The present practice is to permit the grower to incur indebtedness with various merchants, the idea being that the grocer, the implement man, and the lumberman should carry their share of the temporary debt.

With agriculture as the one basis of prosperity in the community and cotton growing an important branch of that agriculture, it is to be expected that the banking interests will take a construc-

tive attitude toward the cotton industry. It is taken for granted that the banker is concerned in the permanent prosperity of agriculture and of the agriculturist. He should look beyond the integrity of the individual grower patron and beyond financing him temporarily to the general prosperity of the industry.

THE MANUFACTURER AND STABILIZATION.

A few years ago, shortly after the boll weevil invaded the long-staple regions of Mississippi and Louisiana, manufacturers using long-staple cotton were disturbed seriously because of the reduced supply. Steps were taken by them to promote its rehabilitation in the old long-staple centers. The Department of Agriculture had previously recommended measures for the extension of long-staple cotton growing, and as a result several new centers have been opened up.

A temporary increase of the supply, however, merely adds complications to the situation for the user. The assurance of a regular supply of staple cotton is much more important to the manufacturer than an increased supply temporarily.

The stabilization of the supply of long-staple cotton desired by the manufacturer involves the stabilization of the growing industry in the new centers. Stabilization can be brought about if the industry can be maintained on a basis profitable to the grower. The alteration of marketing methods to insure the grower full returns for his product is essential to the stabilizing of the long-staple industry in these new centers. It is a severe arraignment of present marketing methods to state that the practices of private buyers have formed one of the greatest obstacles to the establishment of long-staple cotton production, but such is the case. The system rather than the individual buyer is at fault.

Manufacturers have urged the extension of long-staple cotton production to increase and insure a steady supply of raw material without taking constructive action to make the growing of long-staple cotton profitable to the producer. The manufacturers can contribute much to the extension and stabilization of long-staple cotton by studying the problem from the growers' point of view. This does not mean that the manufacturer must pay prices beyond the market or that the growing of a long-staple cotton must be subsidized in any way, but it does mean that the manufacturer must know something of the problems of long-staple cotton production. The manufacturer's interest in the supply of superior cotton must extend beyond the broker and he must do his share to get a fair market price into the hands of the producer. The two principals in the stabilization of long-staple cotton growing are the grower and the manufacturer.

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HONEYBEES: WINTERING, YIELDS, IMPORTS AND
EXPORTS OF HONEY.

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WINTERING OF HONEYBEES, WINTER 1914-15.

The data included in returns from about 650 honey producers in 42 States, covering 80,000 colonies of bees, including full reports from the important honey-producing States, bearing primarily upon the wintering of bees and showing the losses and causes thereof for the past winter, are summarized in Tables 1 and 2.

While the figures are believed to be fairly representative and trustworthy, this can not be assumed in all cases, as some States producing considerable honey failed to furnish enough reports to give full confidence in the State average.

It will be seen by reference to column 1 that bees entered winter quarters in good condition, notwithstanding the poor season in much of the country. Two factors probably contributed largely to this result, the first being that in States where little surplus honey was stored in the spring and early summer many beekeepers refrained from removing honey from the hives, and the second that the fall nectar flow was generally good, permitting the colonies to build up and affording sufficient supplies for winter.

It will be seen by reference to columns 4 and 5 that the average quantity of honey on hand at the beginning of winter was generally in excess of what was assumed by the beekeepers reporting to be

NOTE.—This bulletin will be found of interest to beekeepers and dealers in bee products.

needed to carry a colony through the winter and give it a good start at brood-rearing in the spring.

An interesting circumstance shown by a comparison of the figures in column 4 is that there seems to be little variation between the supply of food required to winter a colony in the different parts of the country, notwithstanding that the period in the Northern States between the fall and spring nectar flows (evidently interpreted by many reporters as the period between honey flows yielding a surplus) is shown in column 2 as from 7 to 9 months, with the bees confined to the hive for as much as 3 or 4 months at a time (column 3) without opportunity for a cleansing flight, while in the Southern States the interval shown between nectar flows is from 4 to 6 months only, and confinement to the hive ranges from a month down to but a few days at a time. The explanation of this uniformity in food requirements under greatly varying conditions is not entirely clear, though the comments accompanying the reports indicate that it may be due in part at least to the greater activity of bees during the winter season as one proceeds southward, the warm days permitting the winter cluster to be frequently broken, with the bees active and flying out. Also in many sections of the South brood-rearing throughout the winter is quite frequent, while in the North colonies which are well cared for and are not compelled to battle with extremely low temperatures are less likely to begin brood-rearing prematurely.

The percentage of the colonies given winter protection, as shown in column 6, *g*, very high in the Northern States, drops off rapidly to almost nothing south of the Potomac and Ohio Rivers and in the Southwestern and Pacific Coast States. In the extreme North a favorite mode of wintering is shown (column 6, *a*) to be in cellars, in the less extreme Northern States mostly by means of double-walled and packed hives (column 6, *b*), while farther south such occasional protection as is given is usually confined to supers packed with absorbent material, to wrappings of tar paper, etc., around the hive, the employment of windbreaks or open sheds, the partial covering of the hive with straw, etc. A number of reports from the Western Plateau States mention the practice of covering all but the entrance of the hive with straw overlaid with earth.

The losses during the past winter, as will be seen by reference to column 7, *j*, Table 2, generally range from 15 to 20 per cent in the more northerly States of the white-clover belt, from 5 to 15 in the lower portions of that belt and in the Southeastern and South-Central States, and in the neighborhood of 5 to 10 per cent in the important honey-producing States of Texas, Colorado, Utah, and California, with but 2 per cent in Arizona. The average for the entire country is 12.6 per cent.

The cause of loss most frequently given is missing or worn-out queens. The most important absolute item of loss is starvation. A serious loss is shown from poor quality of winter stores, usually aster honey, which in some sections, with long confinement, is said to induce dysentery. Late and weak swarms often succumb. Losses of colonies deficient in young bees were heavy in districts where a late summer drought interfered with fall brood-rearing. Various other causes mentioned are smothering and exposure, which have been included with cold, long confinement, robbing, brood disease, mice, moths, ants, and small predatory animals. A considerable percentage of reporters failed to state the cause of death, either from carelessness or perhaps disinclination to mention starvation as the cause. That so many should have been shown to die from the latter cause, which can in a great majority of cases be avoided by moderation in removing surplus honey or absolutely prevented by the proper feeding of sugar sirup in the late fall or early spring, is a regrettable exhibit.

CONDITIONS AND HONEY YIELDS, SEASON 1915.

The number of colonies, spring count, reported this season averages for the entire United States two-tenths of 1 per cent less than last year (Table 3, column 8). Increases of 15 per cent in Texas, 10 per cent in California and Arizona, and rather general increases in the northern tier of States from Michigan westward are offset by decreases of 14 per cent in Missouri, 10 per cent in New York and Indiana, 8 per cent in Illinois, Nebraska, and Arkansas, and smaller percentages in a number of other important honey-producing States.

The condition of the colonies on May 1 (column 9, *a*), largely measured by the number of bees and amount of brood compared with a normal condition of populousness and vigor at that date, was 92.7 per cent for the United States as a whole, being 5.1 per cent lower than on May 1 last year. (See column 9, *b*.) This may be ascribed in part to the late cold spring over much of the country, which delayed brood-rearing, and to some extent to the poor quality of the winter stores in many States, which weakened the colonies.

The condition is shown below 90 in New York, Maryland, Ohio, Illinois, Missouri, Nebraska, Kansas, Oklahoma, and Arkansas, and 90 or slightly above in Pennsylvania, Virginia, Indiana, Iowa, Tennessee, and Alabama. In each of the States named except Kansas it was lower than last year.

The condition of honey plants, shown on May 1 as 93.3 per cent, is 5.8 per cent lower than last season at that date (columns 10, *a*, and 10, *b*.) As weather conditions since May 1 over the country as a whole have been decidedly better for plant growth than last year, when droughty conditions prevailed in many sections, the condition

of most honey plants east of the Rockies improved materially after the date of this inquiry.

The July 1 reports indicated that the honey season had been late from 1 to 3 weeks over most of the country, due to cold and generally wet weather. The prospects in the Ohio Valley region were very poor owing largely to the damage to white clover from former droughts. The crop outlook from clover in the Central Atlantic and New England States and west of the Mississippi was fair to good. The outlook for alfalfa honey in Utah and in sections of adjoining States was unfavorable because of damage to alfalfa from insects. Freezes in Colorado had destroyed the fruit bloom. The relatively poor crop at that date in California was reported as due mostly to light nectar flows from orange and button sage.

The returns from the States that normally produce a fair proportion of their surplus honey crop by July 1 were sufficiently complete to permit of establishing satisfactory estimates except for two States, which are omitted. The reports from Northern and Mountain States which usually produce little surplus by July 1 were not as numerous, and the averages drawn from these are therefore not considered altogether dependable. It has been necessary to omit a number of such States for lack of information. The influence of these upon the United States averages is fortunately not large.

The average yield of surplus honey per colony up to July 1, 1915, for the States reporting is estimated at 18.3 pounds against 20.7 pounds last year. (Columns 11, *a*, and 11, *b*.)

Last year the proportion of the total surplus produced by July 1 was approximately 65 per cent, the early flow being favorable and that later in the summer poor. This year the proportion is 50.6 per cent, the summer bloom having been abundant throughout most of the Northern, Central, and Eastern States. Notwithstanding the season's abundant bloom, the large proportion of rainy and cool days, by suppressing the secretion of nectar, washing nectar from the bloom, and most of all by keeping bees confined to the hive, has resulted in merely a fair crop instead of a heavy one.

The estimate of the usual production by July 1 is 51.9 per cent. These estimates on the proportion of honey usually produced by July 1 (11, *c*) are of much interest, indicating the degree to which the July 1 report may be accepted by producers and others interested in forming a judgment of probable supplies and prices. It appears that, speaking generally, from two-thirds to three-fourths of the surplus is ordinarily produced by that date in the Southern States, including Maryland, Tennessee, and Arkansas, under one-fourth in the extreme Northern and Mountain States, and 40 to 50 per cent in most of the remainder. The usual average for the entire United States is estimated by correspondents to be slightly over half the

year's total. After a few years it will be possible to substitute for these estimates figures based upon the records now being built up.

The average yield for the United States of surplus honey per colony in 1915 according to the September 1 estimate (11, *d*) is 36.2 pounds as against 32.2 pounds in 1914 (11, *e*), an increase over last year of approximately 12 per cent, and a decrease of 11 per cent under the yield of 40.6 pounds in 1913.

These estimates of yield per colony are believed to be somewhat high for the average producer. They are based primarily upon reports from a special list of reporters who are in the main progressive beekeepers, utilizing modern equipment, and obtaining thereby larger yields than the average person who keeps bees. While they are asked to report for the community whenever possible, the reports are often limited to or influenced by the results in their own apiaries. While these averages are checked and modified by returns from the regular crop reports, the figures shown, though below the average for commercial apiaries, are likely above the average for all beekeepers. In any event, the figures on relative number of colonies and yields per colony for 1915, 1914, and 1913 are reasonably comparable, having been furnished by the same reporters, and represent at least the relative production of the three years, as estimated September 1, 1915.

In May, 1914, the correspondents of the bureau estimated the number of colonies to be 103.7 per cent of 1913, while this year the number is shown as 99.8 per cent of 1914. The total production this year, so far as could be estimated on September 1, will be 112 per cent of 1914 and 92.3 per cent of 1913.

The total absolute production of surplus honey in 1915 can not be satisfactorily estimated because of the lack of dependable knowledge of the actual number of colonies.

It is estimated that of the total production, California furnished this year about 12 per cent, Texas 8 per cent, and Iowa and New York 6 per cent each.

The form of honey produced (Table 4, 12) shows that this year, in comparison with last, a slightly less proportion of comb and extracted honey and a slightly greater proportion of bulk comb honey has been obtained.

The Northern States generally, with the exception of Illinois, Wisconsin, and Nebraska, show a high proportion (one-half to two-thirds) of their production in the form of comb honey in sections, while in the South and West generally this form is only from one-third to one-half of all, and in a few States very much less. Conversely, the proportion of bulk comb or chunk honey is relatively high in the Southern States and of extracted in the Western, the latter form comprising 90

per cent of the total crop in Arizona, 85 per cent in Utah and New Mexico, and 82 per cent in California.

The reports on disposition of honey (Table 4, 13) indicate that while for the entire United States 60.8 per cent of the honey removed from the hive is consumed locally, more than one-half is shipped out of the locality where produced in the States of Vermont, New York, Florida, Kentucky, Louisiana, Texas, Wyoming, Colorado, New Mexico, Arizona, Utah, Idaho, and California. Of the 39.2 per cent thus entering this year the main trade channels as a distinctly commercial crop, California furnished about one-fourth, mostly extracted, and Texas one-eighth, practically all extracted or bulk comb honey.

The losses shown to colonies during the season from diseases (Table 4, 14) averages 1.5 per cent for the United States, being most severe in the States of New Jersey, Pennsylvania, Nebraska, Utah, Idaho, and California. The principal bee diseases mentioned were American foulbrood and European foulbrood.

The strength of colonies on September 1 compared with normal strength on that date (Table 4, 15) averaged 97.3 per cent for the United States, being above normal in many of the Northern States. The long drawn out, even if intermittent, flow of nectar over much of the country, while not resulting in a heavy honey crop, has encouraged an unusual amount of brood rearing during the summer, so that colonies are stronger than usual in those sections.

Information reaching the bureau on mid-September indicates that the fall flow is proving very abundant throughout the Middle West and under these conditions, which are believed to obtain also in most of the country east of the Alleghenies, bees in the territory indicated are rapidly accumulating a comfortable supply of winter stores. In many sections they are storing considerable surplus.

IMPORTS AND EXPORTS OF HONEY.

As a result, unquestionably, of the interference of the European war with the exports to that continent of honey from Mexico and the West Indies, much more than the usual supply from the countries to the south has been forced upon the United States markets since the war began.

The total foreign imports into this country for the five fiscal years ending June 30, 1910 to 1914, inclusive, were 104, 113, 115, 116, and 75 thousands of gallons, respectively, of which normally about 45,000 gallons came from Mexico, about 50,000 from Cuba, and 5,000 from Haiti. The import duty on this honey from Cuba is 8 cents per gallon, and from other foreign countries 10 cents. For the first three months of the fiscal year 1915, beginning July 1, 1914, the imports were 53,000 gallons, during the next quarter, ending December 31, they were 85,000 gallons. For the entire fiscal year they amounted

to 303,965 gallons, about three times the quantity imported from foreign countries in any previous entire year, having a stated value of approximately \$124,843. Of the total imports for the year, 92,876 gallons came from Mexico, 164,042 from Cuba, 7,309 from Haiti, and 33,571 from Santo Domingo.

In addition to the imports mentioned, this country also received honey from the island possessions, that from Porto Rico and Hawaii this year exceeding slightly in value and probably also in quantity the imports just mentioned from foreign countries. Hawaii ordinarily furnishes shipments to the value of \$35,000; the imports this year totaled \$35,536. Porto Rico, by reason of the rapid development of this industry in that island, increased its shipments from the value of \$8,018 in 1910 to \$17,904 in 1911, \$42,000 in 1912, \$60,000 in 1913, \$91,000 in 1914, and for the present year to \$94,895.

Practically all of this honey is extracted, and that most of it is of the low grades, used by bakers and not for table use, is indicated by the price of the foreign imports, which averaged during the five years ending June 30, 1914, between 50 and 60 cents per gallon. The pressure of the heavy supply on the markets lowered the import price of foreign honey to 41 cents per gallon before December of last year, and the average import price for the fiscal year just closed is about 41.1 cents.

The total honey crop of the continental United States in 1909 was reported by the census to be about 55,000,000 pounds; expressed in terms of gallons, roughly 5,000,000. This represents production on farms alone and is an admittedly low estimate even for the farm production, as only a little over half of the farms showing bees gave a report on honey production. It is impossible to know what proportion of these farms failed to report honey production because no honey was actually obtained from the bees, and what because of oversight, indifference, or lack of information. No record appears to have been taken of the large production by beekeepers not farmers.

Compared with the total production of the United States as reported by the census, the heavy imports for the present fiscal year, which from all sources probably total over 600,000 gallons, are therefore about 12 per cent, though probably considerably less, if compared with the actual production. Compared with the portion of the home crop actually marketed, however, the percentage would be much larger, and its absolute bulk compared to the quantity of low-grade extracted honey produced here for market is so great that it has seriously interfered with the marketing of the latter and, combined with the financial depression in the South, where the lower grades are largely produced and consumed, has forced the prices of such grades to extremely low figures. The heavy inward movement of foreign

honey shows no present signs of abatement and must be accepted as a probable factor for some time to come.

The quantities of honey exported are not stated in the official returns of exports, but the values of total exports of this commodity for the fiscal years 1910 to 1914, inclusive, were 159, 82, 213, 182, and 136 thousands of dollars, respectively. About two-thirds of this honey is ordinarily shipped from the Pacific coast, 10 to 20 per cent from Porto Rico and Hawaii, and most of the remainder from the port of New York. Evidently, from its source, it is mostly extracted. The exports have been principally to Germany, which has taken from 40 to 60 per cent annually. Canada has taken from 15 to 20 per cent. The exports to the United Kingdom amounted to \$59,000 in 1910, but had fallen to \$4,000 in 1914. The exports for the present fiscal year, beginning July 1, 1914, just prior to the opening of the European war, amounted to approximately \$114,000, the exports to Germany being \$10,200, to Denmark \$14,375, to the United Kingdom \$53,763, and to Canada \$14,930. The exports are therefore seen to have suffered some reduction from past years as a result of the war.

The effect of both these movements—increased imports and decreased exports—is to increase the amount of honey that must be disposed of in our home markets. It will be observed that this commerce is concerned in but very slight measure with comb honey, for good grades of which the home market furnishes sufficient demand.

TABLE 1.—*Fall condition of honey bees, 1914; winter confinement, food supplies, and extra protection given during winter 1914-15.*

State.	1	2	3	4	5	6							
	Condition of colonies at beginning of last winter (fall 1914).	Usual length of time between fall and spring nectar flows.	Longest period confined to hives in usual winter without a flight.	Honey needed to winter a colony outdoors.	Honey on hand per colony at beginning of last winter.	Extra winter protection furnished colonies.							
						Cellars.	Double-walled and packed hives.	Packed and in cellar (a and b not separated).	Packed, super.	Wrappings of tar paper, etc.	Straw covering and miscellaneous.	Total per cent given winter protection.	
	(a)	(b)	(c)	(d)	(e)	(f)	(g)						
	P. ct.	Mos.	Mos.	Lbs.	Lbs.	P. ct.	P. ct.	P. ct.	P. ct.	P. ct.	P. ct.	P. ct.	
Maine.....	100												
New Hampshire.....	100												
Vermont.....	89	7.6	3.6	29	25	67	14				14		95
Massachusetts.....	98	6.2	1.9	29	34	17	39	20					76
Connecticut.....	105	6.1	1.7	35	28	6		46					50
New York.....	85	7.2	2.8	31	29	25	33	22					80
New Jersey.....	99	5.7	2.0	25	27		30						30
Pennsylvania.....	94	7.0	2.2	31	30	1	35	4	15	3	2		60
Maryland.....	90	6.0	1.3	30	30	1	9		10	5			25
Virginia.....	95	5.7	1.3	28	32				3		1		4
West Virginia.....	90	7.0		35	35		10						10
North Carolina.....	90	4.6	1.2	26	25		5						5
South Carolina.....	101	5.2	1.0	30	31								2
Georgia.....	97	4.8	1.0	27	29		2				1		1
Florida.....	97	4.2	.5	40	40								0
Ohio.....	92	6.3	2.0	29	33	10	26		3	6			45
Indiana.....	94	6.4	2.0	31	34	3	30		4	3			40
Illinois.....	89	6.8	2.5	32	30	20	26		2		2		50
Michigan.....	96	7.0	3.2	29	29	30	13	34			3		80
Wisconsin.....	100	7.0	3.4	31	34	74	16	5		2			97
Minnesota.....	92	7.6	3.3	36	38	69		30					99
Iowa.....	86	6.5	2.2	32	28	40	10	21		2	2		75
Missouri.....	78	6.4	1.6	33	26		5		12		3		20
South Dakota.....	95	7.0	2.7	37	41	44	1	6			19		70
Nebraska.....	100	6.4	1.3	32	35	1	30		12		7		50
Kansas.....	90	5.7	1.6	33	36		1		3	1	5		10
Kentucky.....	99	5.9	1.4	34	42		2		6				8
Tennessee.....	96	5.5	1.1	32	36		2			2			4
Alabama.....	91	5.0	.6	35	36				1				1
Mississippi.....	100	5.6	.5	29	32								0
Louisiana.....	92		.5	30	32								0
Texas.....	104	4.1	.6	34	41				1				1
Oklahoma.....	81	5.9	1.2	30	25					8			8
Arkansas.....	85	4.0	.9	35									0
Wyoming.....	102	8.5	1.4	25	38	26	9			30			65
Colorado.....	88	7.7	1.2	37	39	1	1		5	4	1		12
New Mexico.....	104	6.3	.5	36	36		2		2				4
Arizona.....	100	3.6	.1	33	34								0
Utah.....	100	8.8	1.4	49	44	1	30		12	7			50
Nevada.....	100	7.0	1.0	40	35								0
Idaho.....	95	7.3	3.1	37	39	3	4	20	2	1	25		55
Washington.....	109	6.4	1.2	37	41		3		1	1			5
Oregon.....	99	5.0	.7	26	31		7						7
California.....	103	4.5	.5	33	44								0
United States average.....	93.6	5.8	1.5	31.9	33.5	9.1	9.0	4.3	2.5	.9	1.0		26.8

TABLE 2.—*Winter losses of honey bees; causes and percentage of colonies lost, winter 1914-15.*

State.	7 Causes and percentages of winter losses.									
	(a)	(b)	(c)	(d)	(e)	(f)	(g)	(h)	(i)	(j)
	Queen lost or impotent.	Starvation.	Cold, exposure, smothering.	Moths and ants.	Foul brood and other diseases.	Poor honey, dysentery.	Late and weak swarms.	Lack of young bees.	Miscellaneous and unknown.	Total loss of colonies.
	<i>P. ct.</i>	<i>P. ct.</i>	<i>P. ct.</i>	<i>P. ct.</i>	<i>P. ct.</i>	<i>P. ct.</i>	<i>P. ct.</i>	<i>P. ct.</i>	<i>P. ct.</i>	<i>P. ct.</i>
Vermont.....	0.1	0.4	0.1	.....	.....	2.7	0.1	.....	7.6	11.0
Massachusetts.....	.....	.....	2.1	.....	.....	.5	11.1	.....	.....	13.7
Connecticut.....	.....	16.0	.....	.....	.....	.....	.....	.....	.....	16.0
New York.....	1.2	.6	.1	.....	.....	9.4	6.4	.....	2.1	19.8
New Jersey.....	2.2	.....	.....	.....	0.1	.5	1.5	1.3	.5	6.1
Pennsylvania.....	2.2	1.2	1.7	.....	.....	1.8	2.7	.2	5.9	15.7
Maryland.....	.3	4.7	.....	0.2	.....	3.7	1.4	1.1	.....	11.4
Virginia.....	1.5	1.8	.1	.6	.....	1.3	1.4	.4	4.1	11.2
West Virginia.....	.....	.....	.....	.....	.....	5.7	.....	.....	.....	5.7
North Carolina.....	.4	2.6	.....	1.7	.....	.....	.4	.....	.....	5.1
South Carolina.....	5.7	3.3	.....	3.7	.....	.....	.4	.....	.....	13.1
Georgia.....	2.8	10.7	.....	1.1	.....	.....	.....	.....	.1	14.7
Florida.....	2.3	.....	.....	.....	.....	.....	2.3	.....	3.8	8.4
Ohio.....	.8	.....	2.6	.....	1.5	5.4	.2	5.5	.1	16.1
Indiana.....	.9	1.4	2.2	.....	.6	2.9	.....	1.7	1.1	10.8
Illinois.....	2.1	.5	2.5	.....	.....	4.3	1.8	.....	.1	11.3
Michigan.....	2.9	2.6	1.6	.....	.7	2.1	.2	.....	.6	10.7
Wisconsin.....	4.1	.....	.1	.....	.....	.6	.....	.....	.6	5.4
Minnesota.....	.2	10.5	.....	.....	.....	5.3	.....	.....	.5	16.5
Iowa.....	2.4	.1	.....	.....	1.3	3.4	2.7	2.0	1.1	13.0
Missouri.....	.....	.....	4.3	.....	.....	3.3	.....	.....	23.4	31.0
South Dakota.....	.4	2.8	3.0	.....	.....	.....	.....	.8	.8	7.8
Nebraska.....	2.4	3.6	2.6	.....	.....	3.6	.....	.....	3.6	15.8
Kansas.....	.4	3.5	.1	.....	.....	.....	3.3	.....	.1	7.4
Kentucky.....	.9	2.7	.7	.1	.2	3.2	.....	.....	1.7	9.5
Tennessee.....	1.4	3.7	.3	.3	.....	1.0	1.7	.....	.5	8.9
Alabama.....	.8	10.5	.....	.1	.1	.....	.....	.....	5.8	17.3
Mississippi.....	.7	11.4	.....	1.3	2.2	.5	.....	.....	7.1	23.2
Louisiana.....	2.1	5.6	.....	.....	.....	.....	.....	.....	.....	7.7
Texas.....	1.5	3.1	.....	.2	.2	.....	1.5	.....	.6	7.1
Oklahoma.....	1.0	1.0	2.4	.....	.....	.3	2.0	.....	8.7	15.4
Arkansas.....	.....	25.0	.....	.....	.....	.....	.....	.....	.....	25.0
Wyoming.....	1.7	17.4	.....	.....	.....	.....	.....	.....	.....	19.1
Colorado.....	2.3	.5	1.4	.....	.6	.8	1.5	1.1	2.3	10.5
New Mexico.....	1.7	.....	.....	.....	.....	.....	.....	2.5	5.0	9.2
Arizona.....	1.5	.....	.....	.....	.2	.....	.3	.....	.....	2.0
Utah.....	4.8	.....	1.0	.....	.1	3.3	.....	1.0	.3	10.5
Nevada.....	.....	.....	.....	.....	.....	.....	.....	.....	5.0	5.0
Idaho.....	2.6	.2	.2	.....	.....	.6	.6	1.1	.6	5.9
Washington.....	.9	.2	16.9	.....	.....	.....	.8	.....	1.0	19.8
Oregon.....	2.2	.....	.....	.2	1.0	.....	.....	.....	.5	3.9
California.....	2.5	.1	.....	.....	1.2	.....	.3	.....	.9	5.0
United States, average.....	1.5	3.2	.9	.3	.3	2.1	1.1	.4	2.8	12.6

TABLE 3.—*Number of colonies (spring count) 1915, condition of bees and honey plants May 1, estimated yield of surplus honey July 1, and indicated yield Sept. 1 for entire season, 1915.*

State.	8 Number of colonies, spring count, 1915, compared with previous year.	9 Condition of colonies compared with normal.		10 Condition of honey plants com- pared with normal.		11 Yield of surplus honey per colony.						
		(a) May 1, 1915.	(b) May 1, 1914.	(a) May 1, 1915.	(b) May 1, 1914.	(a) Reported to July 1, 1915.	(b) Reported to July 1, 1914.	(c) Per cent of total surplus, usually produced by July 1.	(d) For entire sea- son, estimated Sept. 1.			
									1915.	1914.	1913.	
Maine.....	No. 100	P. ct. 99	P. ct. 94	P. ct. 99	P. ct. 93	Lbs. 8	Lbs. 8	P. ct. 18	Lbs. 25	Lbs. 30	Lbs. 38	
New Hampshire.....	103	100	91	98	95	18	25	50	28	30	27	
Vermont.....	96	95	95	100	98	5	4	12	40	20	33	
Massachusetts.....	101	96	90	93	91	12	7	47	22	22	31	
Rhode Island.....	100	98	96	90	93	35	10	10	35	40	45	
Connecticut.....	110	98	85	100	90	5	6	17	35	28	35	
New York.....	90	88	95	98	95	13	9	30	45	22	37	
New Jersey.....	98	98	98	97	98	5	8	54	25	12	40	
Pennsylvania.....	96	91	94	94	93	10	15	40	28	28	45	
Delaware.....	98	96	98	94	95	12	18	50	12	20	21	
Maryland.....	102	88	95	91	93	20	32	70	20	25	40	
Virginia.....	106	92	93	87	90	31	32	72	40	35	38	
West Virginia.....	95	93	95	92	94	21	24	64	30	25	20	
North Carolina.....	102	96	92	93	91	21	24	64	28	28	25	
South Carolina.....	101	93	91	92	91	21	21	68	20	18	25	
Georgia.....	100	93	94	92	93	28	30	72	30	30	30	
Florida.....	100	93	97	92	95	48	46	60	45	42	50	
Ohio.....	98	88	100	93	100	5	14	46	20	23	50	
Indiana.....	90	90	96	90	95	7	16	51	24	25	60	
Illinois.....	92	85	98	82	85	6	8	45	25	17	60	
Michigan.....	104	97	98	98	94	13	26	45	45	37	50	
Wisconsin.....	103	98	110	100	93	14	24	40	50	40	60	
Minnesota.....	102	97	98	99	95	12	14	24	50	35	60	
Iowa.....	94	91	100	95	95	16	15	40	45	25	65	
Missouri.....	86	84	85	86	85	18	5	51	33	8	30	
North Dakota.....	105	100	102	100	100	1	10	9	55	25	50	
South Dakota.....	105	93	105	98	98	6	6	18	40	30	50	
Nebraska.....	92	88	95	96	95	6	6	18	40	30	50	
Kansas.....	100	88	86	95	85	6	8	29	30	20	25	
Kentucky.....	102	95	95	91	93	25	8	48	35	25	40	
Tennessee.....	102	92	95	88	92	26	25	67	17	28	30	
Alabama.....	101	91	97	90	95	30	30	85	30	28	35	
Mississippi.....	100	95	93	92	95	25	26	77	33	33	35	
Louisiana.....	96	90	91	90	90	17	42	76	33	30	35	
Texas.....	115	97	115	96	115	17	42	76	40	55	35	
Oklahoma.....	99	89	98	97	96	2	5	33	30	25	35	
Arkansas.....	92	87	92	88	90	15	12	65	20	20	30	
Montana.....	125	97	105	100	100	1	2	3	63	62	35	
Wyoming.....	120	103	108	100	100	1	2	3	70	70	75	
Colorado.....	101	95	110	97	107	1	2	3	29	43	60	
New Mexico.....	115	96	105	103	105	15	7	10	40	55	50	
Arizona.....	110	104	105	110	105	86	59	78	70	60	70	
Utah.....	105	99	105	98	102	8	11	15	50	65	70	
Nevada.....	100	100	100	100	100	0	4	7	65	40	75	
Idaho.....	105	99	115	101	110	0	4	7	63	56	55	
Washington.....	103	100	102	105	100	1	3	19	44	40	45	
Oregon.....	98	99	105	100	100	16	15	45	30	35	40	
California.....	110	100	107	100	120	35	45	52	75	75	36	
United States average.....	99.8	92.7	97.8	93.3	99.1	18.3	20.7	51.9	36.2	32.2	40.6	

TABLE 4.—*Form of honey produced, percentage used locally and that sold to outside markets, losses of colonies during season from disease, and strength of colonies on Sept. 1, 1915.*

State.	12 Form of honey produced.						13 Disposition.		14	15
	(a) Comb in sections.		(b) Extracted.		(c) Bulk comb "chunk."		(a)	(b)	Colo- nies lost from disease, 1915.	Strength of colonies Sept. 1, com- pared with normal.
	1915	1914	1915	1914	1915	1914	Used lo- cally.	Out- side mar- kets.		
Maine ¹	P. ct. 80	P. ct. 80	P. ct. 17	P. ct. 15	P. ct. 3	P. ct. 5	P. ct. 75	P. ct. 25	P. ct. 5.0	P. ct. 88
New Hampshire ¹	85		15		0				0	100
Vermont ¹	90	66	8	28	2	6	5	95	2.0	110
Massachusetts ¹	87	67	13	32	0	0.7	94	6	1.0	105
Rhode Island ¹	20	5	80	95	0	0	100	0	1.0	105
Connecticut.....	61	48	29	47	10	5	83	17	.2	97
New York.....	61	47	39	50	0	3	45	55	.9	104
New Jersey ¹	77	25	23	75	0	0	96	4	5.0	94
Pennsylvania.....	60	65	30	29	10	6	75	25	4.0	95
Delaware ¹	60		30		10				0	100
Maryland.....	85	69	10	22	5	9	80	20	.8	105
Virginia.....	75	87	13	12	12	1	75	25	2.3	103
West Virginia ¹		57		38		5				
North Carolina ¹	34	45	17	30	49	25	51	49	0	101
South Carolina.....	40		30		30		98	2	.4	98
Georgia ¹	40	28	16	33	44	39	75	25	1.0	94
Florida ¹	55	11	45	88	0	1	42	58	0	80
Ohio.....	65	66	32	32	3	2	75	25	2.0	95
Indiana.....	64	52	21	36	15	12	97	3	1.5	100
Illinois ¹	34	42	65	56	1	2	59	41	2.0	96
Michigan.....	54	56	46	43	0	1	54	46	2.0	96
Wisconsin.....	43	41	57	58	0	1	58	42	1.5	97
Minnesota ¹	50	36	45	63	5	1	55	45	.1	106
Iowa.....	58	56	40	42	2	2	65	35	2.0	102
Missouri.....	34	32	37	38	29	30	95	5	2.4	102
North Dakota ¹										
South Dakota.....	62	77	30	22	8	1	85	15	2.0	103
Nebraska ¹	36	43	63	42	1	15	64	36	5.0	100
Kansas ¹	65	67	25	28	10	5	99	1	.1	99
Kentucky.....	45	49	50	33	5	18	33	67	1.0	98
Tennessee.....	22	31	28	23	50	46	88	12	0	89
Alabama.....	32	34	42	41	26	25	55	45	0	95
Mississippi.....	19	49	41	26	40	25	71	29	1.0	94
Louisiana ¹	10	0	80	100	10	0	35	65	0	100
Texas.....	1	4	52	51	47	45	35	65	.5	95
Oklahoma ¹	37	36	15	17	48	47	99	1	.3	100
Arkansas ¹	28	25	32	15	40	60	92	8	0	94
Montana ¹	70		27		3		67	33	3.0	95
Wyoming ¹	97	92	3	8	0	0	6	94	.3	100
Colorado.....	70	67	30	30	0	3	23	77	2.0	89
New Mexico.....	5	31	85	61	10	8	42	58	1.4	95
Arizona.....	10	6	90	94	0	0	36	64	1.0	96
Utah ¹	15	17	85	83	0	0	32	68	4.0	95
Nevada ¹										
Idaho ¹	60	47	37	51	3	2	23	77	5.0	101
Washington ¹	32	46	68	54	0	0	54	46	2.0	95
Oregon ¹	48	64	52	34	0	2	92	8	0	90
California.....	17	18	82	79	1	3	13	87	4.5	97
United States average.....	40.7	41.7	41.3	42.1	18.1	16.2	60.8	39.2	1.5	97.3

¹ Not enough reports for fully dependable averages.

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UNITED STATES DEPARTMENT OF AGRICULTURE
BULLETIN No. 301

Contribution from the Bureau of Biological Survey
HENRY W. HENSHAW, Chief

Washington, D. C.



October 29, 1915

**SILVER FOX FARMING IN EASTERN
NORTH AMERICA**

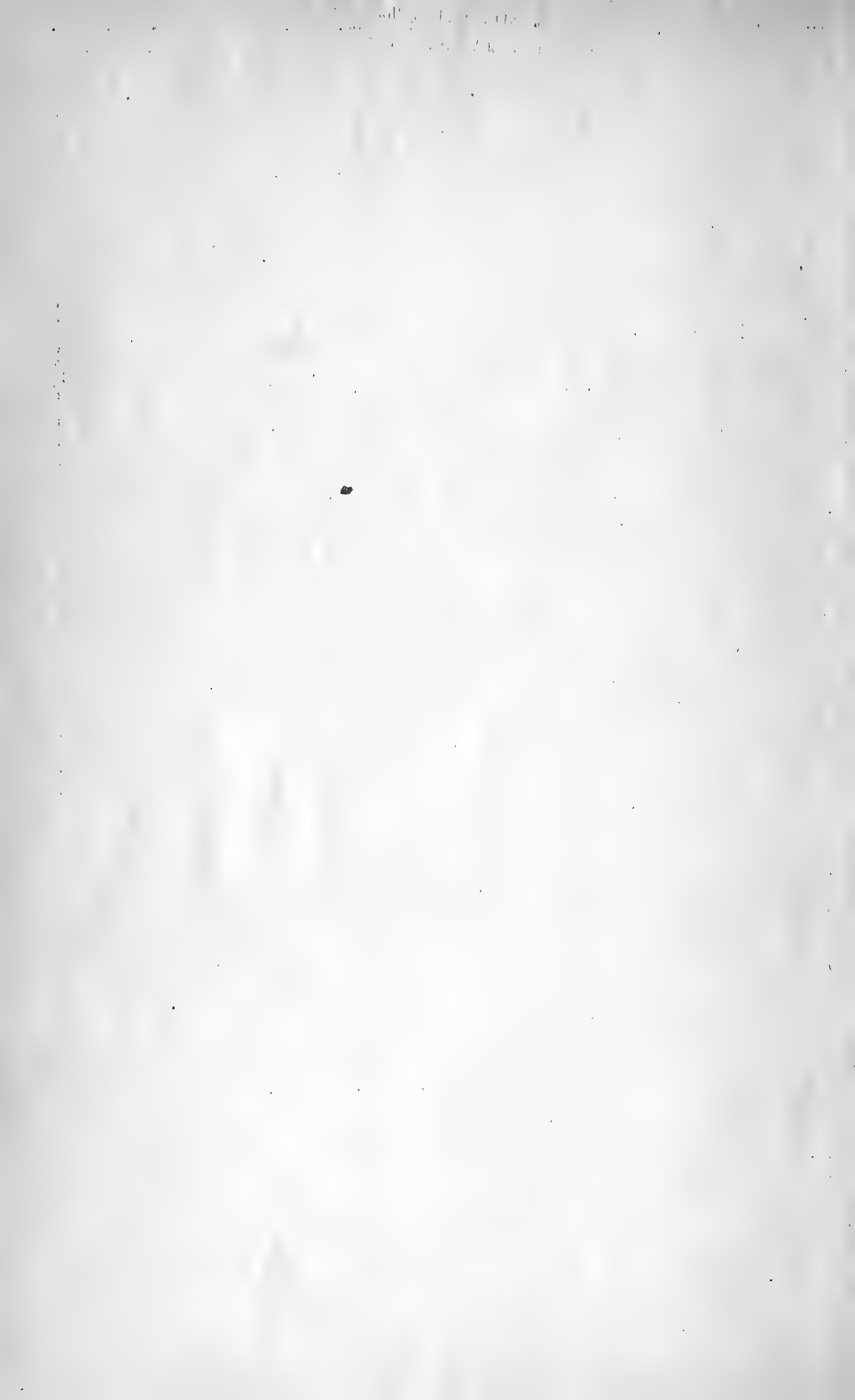
By

NED DEARBORN, Assistant Biologist

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UNITED STATES DEPARTMENT OF AGRICULTURE
BULLETIN No. 302

Contribution from the Office of Markets and Rural Organization
CHARLES J. BRAND, Chief

Washington, D. C.

September 15, 1915

APPLE MARKET INVESTIGATIONS
1914-15

By

CLARENCE W. MOOMAW, Specialist in Cooperative Organization,
and

M. M. STEWART, Assistant in Market Grades and Standards

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VALLEY

EXPLORED

1880

UNITED STATES DEPARTMENT OF AGRICULTURE
BULLETIN No. 304

Contribution from the Office of Public Roads and Rural Engineering
LOGAN WALLER PAGE, Director

Washington, D. C. PROFESSIONAL PAPER November 19, 1915

[Revision of Office of Experiment Stations Bulletin 243]

LAND DRAINAGE BY MEANS OF
PUMPS

By

S. M. WOODWARD, Drainage Engineer

Revised with special reference to the Upper Mississippi Valley by C. W. OKEY,
Senior Drainage Engineer

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UNITED STATES DEPARTMENT OF AGRICULTURE
BULLETIN No. 305

Contribution from the States Relations Service
A. C. TRUE, Director

Washington, D. C.

PROFESSIONAL PAPER

November 11, 1915

EXERCISES
WITH PLANTS AND ANIMALS FOR
SOUTHERN RURAL SCHOOLS

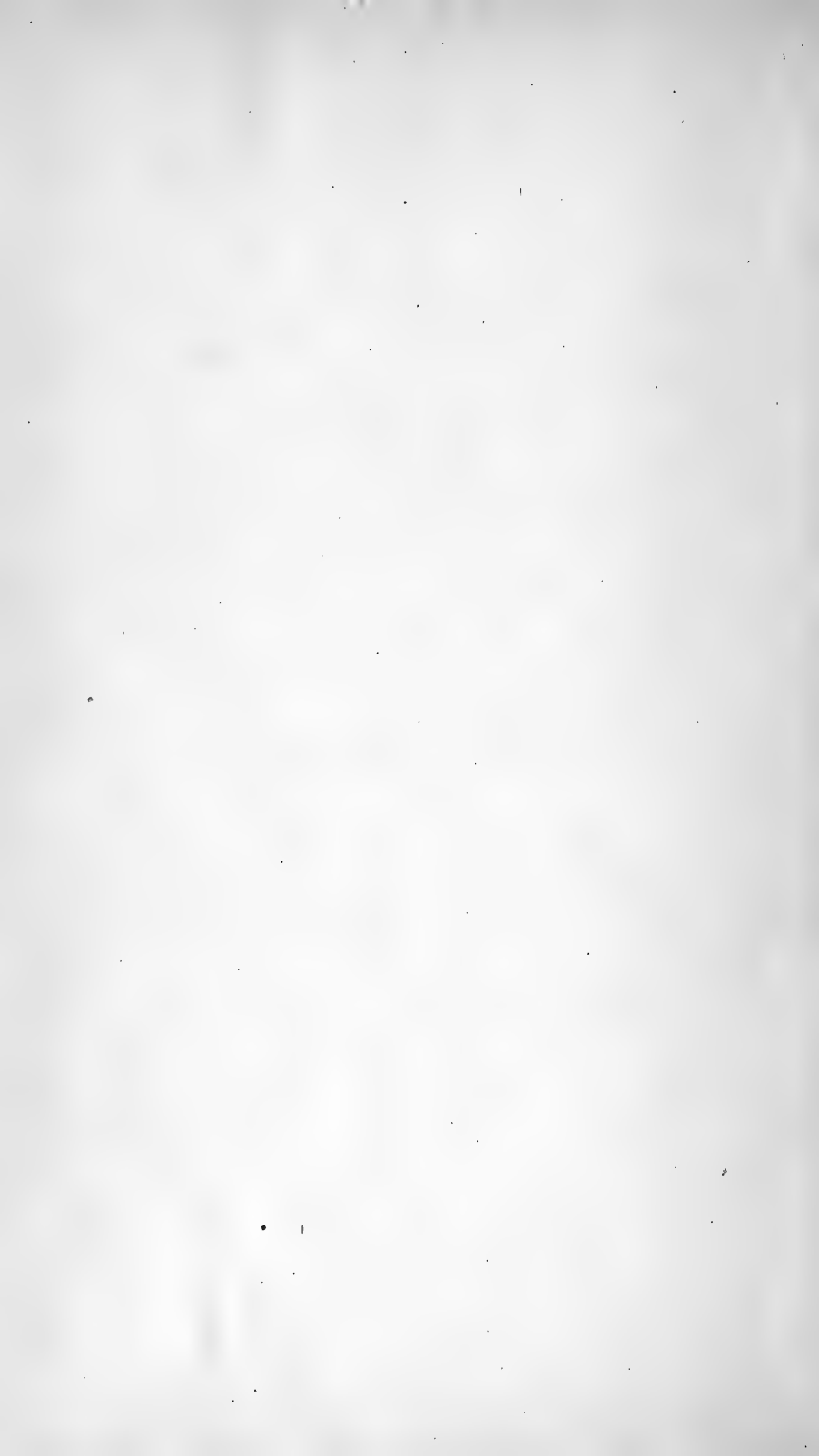
By

E. A. MILLER, Specialist in Agricultural Education

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UNITED STATES DEPARTMENT OF AGRICULTURE

BULLETIN No. 308

Contribution from the Forest Service
HENRY S. GRAVES, Forester

Washington, D. C.

PROFESSIONAL PAPER

November 22, 1915

SHORTLEAF PINE:
ITS ECONOMIC IMPORTANCE AND
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By

WILBUR R. MATTOON, Forest Examiner

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THE
HISTORY OF
THE
CITY OF
NEW-YORK

UNITED STATES DEPARTMENT OF AGRICULTURE

BULLETIN No. 312

Contribution from the Bureau of Soils
MILTON WHITNEY, Chief

Washington, D. C.

PROFESSIONAL PAPER

November 5, 1915

PHOSPHATE ROCK AND METHODS
PROPOSED FOR ITS UTILIZATION
AS A FERTILIZER

By

WILLIAM H. WAGGAMAN and WILLIAM H. FRY

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UNITED STATES DEPARTMENT OF AGRICULTURE
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Contribution from the Bureau of Animal Industry
A. D. MELVIN, Chief

Washington, D. C.



November 13, 1915

**FEATURES OF THE SHEEP INDUSTRIES OF
UNITED STATES, NEW ZEALAND, AND
AUSTRALIA COMPARED**

By

**F. R. MARSHALL, Senior Animal Husbandman in Sheep and
Goat Investigations, Animal Husbandry Division**

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UNITED STATES DEPARTMENT OF AGRICULTURE
BULLETIN No. 314

Contribution from Office of Public Roads and Rural Engineering
LOGAN WALLER PAGE, Director

Washington, D. C.

PROFESSIONAL PAPER

December 10, 1915

METHODS FOR THE EXAMINATION OF
BITUMINOUS ROAD MATERIALS

By

PRÉVOST HUBBARD, Chemical Engineer, and
CHARLES S. REEVE, Chemist

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UNITED STATES DEPARTMENT OF AGRICULTURE
BULLETIN No. 316

Contribution from the Forest Service
HENRY S. GRAVES, Forester

Washington, D. C.

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December 20, 1915

WILLOWS:
THEIR GROWTH, USE, AND IMPORTANCE

By

GEORGE N. LAMB, Forest Examiner

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UNITED STATES DEPARTMENT OF AGRICULTURE

BULLETIN No. 320

Contribution from the Bureau of Plant Industry
WM. A. TAYLOR, Chief

Washington, D. C.



January 24, 1916

FARM PRACTICE IN THE CULTIVATION
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By

H. R. CATES, Scientific Assistant
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UNITED STATES DEPARTMENT OF AGRICULTURE
BULLETIN No. 321

OFFICE OF THE SECRETARY

Contribution from the Office of Farm Management, W. J. Spillman, Chief

Washington, D. C.



January 12, 1916

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By

H. N. HUMPHREY, Scientific Assistant

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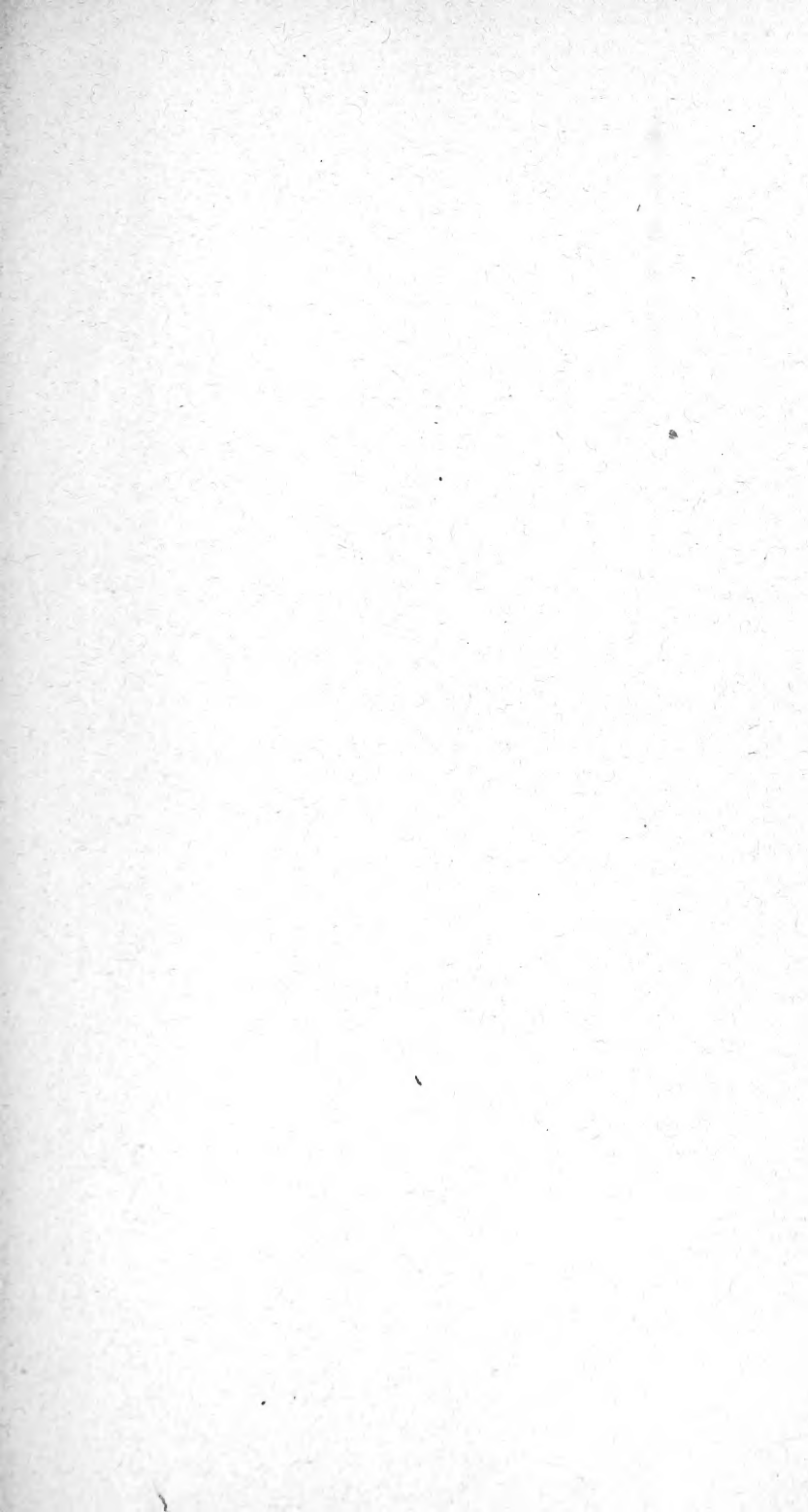
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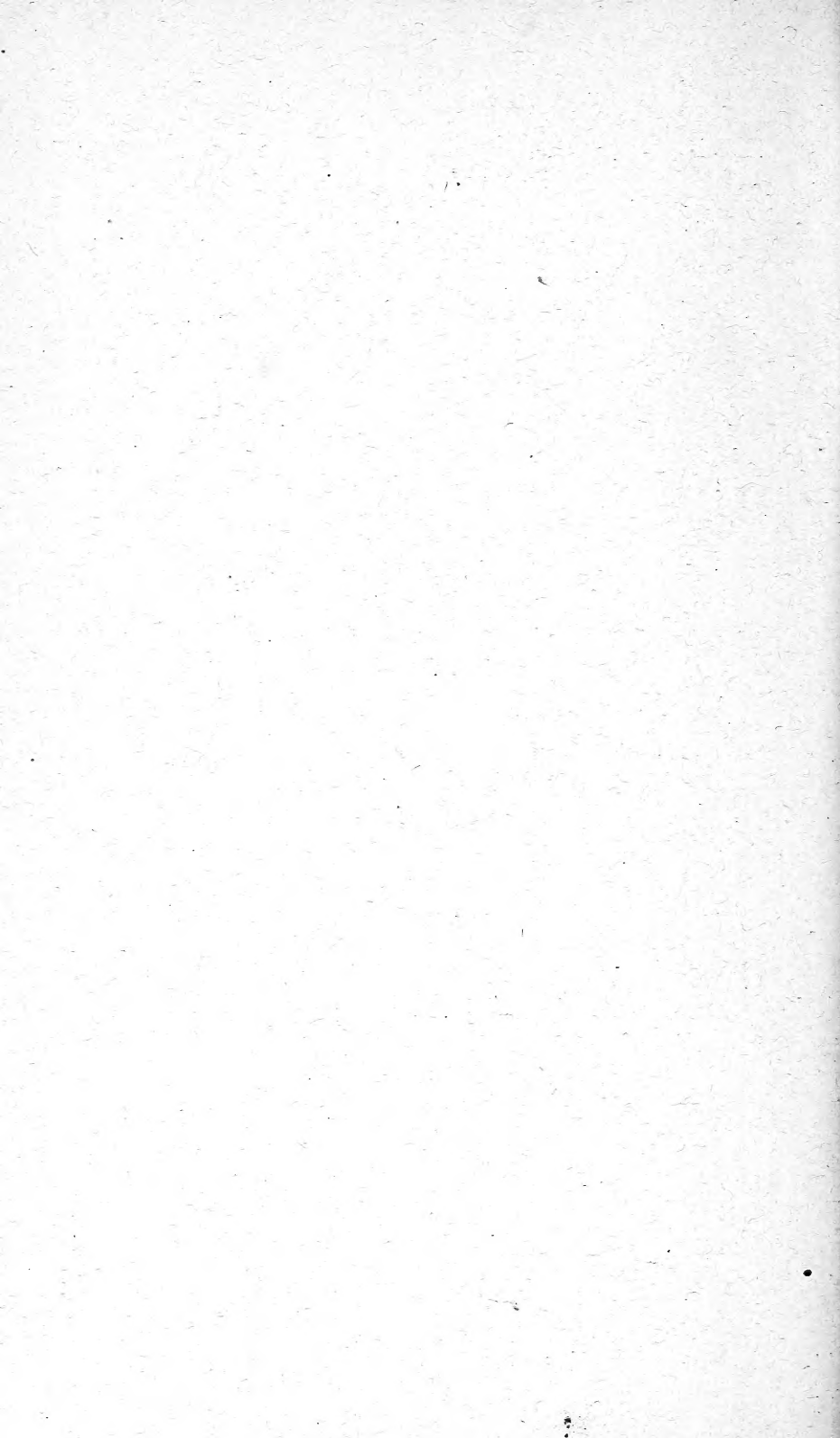
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